ANIMALS OF LAND AND SEA

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BY

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PREFACE

In the following pages an attempt is made to present the animal world as a living unit, showing the interrelationships of the various divisions, and the relations of the whole to the plant world, to physical conditions, and to man. Such a treatment is complementary to the usual one in which the various animal types are taken up in sequence and separately discussed.

The ascertained facts concerning the various forms of animal life mentioned in the succeeding chapters are so very widely scattered through such a vast number of publications that it has not been possible to give references to the original sources consulted in the preparation of this book; indeed, an adequate bibliography would occupy more space than the entire text. Few people, perhaps, realize that the mere recitation of the names of the insects already known to us at the rate of four a minute for eight hours every day would require about ten months, and nearly three months additional would be required to name the remaining forms of animal life. Yet the name of an animal alone is nothing more than a key to its relationships and the clue by means of which we are enabled to search out in our libraries the information in regard to it.

It is unfortunately quite impossible to give a complete list of all those numerous friends who have been so kind as to make suggestions of various sorts in regard to the treatment of different animal types, and to check up for me statements made concerning animals with which I have only a slight personal acquaintance.

I am under special obligations to Dr. John C. Merriam, Dr. Walter K. Fisher, Dr. Asa C. Chandler, Dr. John M. Aldrich, Dr. James A. Hyslop and Dr. Adam Böving, who were so good as to read almost the entire manuscript; to Dr. Henry B. Bigelow, who reviewed the section dealing with the biology

of the sea; to Dr. Henry B. Ward, who looked over the portion dealing with the biology of fresh waters; and to Dr. Charles W. Richmond, Dr. Alexander Wetmore, Dr. Thomas Barbour, Dr. Albert Mann, Dr. Waldo L. Schmitt, Mr. Raymond C. Shannon, Mr. Herbert S. Barber and Mr. Clarence R. Shoemaker to whom certain sections were referred.

Messrs. Wetmore, Shannon, A. N. Caudell and Barber were so generous as to provide me with hitherto unpublished information from their personal notes, and I owe to Mr. Barber the remarkable photographs of flies and moths reproduced on the plates.

For the most part the figures are taken from previous publications by other authors, to whom they are accredited. Those with the designation "Bur. Ent." are from the publications of the Bureau of Entomology, Department of Agriculture; "Bur. Fish." indicates the Bureau of Fisheries, Department of Commerce; "U. S. N. M." stands for the United States National Museum; and "S. I." for the Smithsonian Institution.

To Mr. Samuel Henshaw, the Director of the Museum of Comparative Zoölogy at Cambridge, Massachusetts, I am deeply indebted for permission to reproduce those figures which are taken from the publications of that institution, and I am under similar obligations to the Cambridge University Press, of Cambridge, England.

Except for those portraying insects the plates are all from photographs of living animals taken at the National Zoölogical Park (Smithsonian Institution), Washington, D. C., which were most generously given me by the late Mr. Ned Hollister, the Superintendent.

In the preparation of the text figures I have had the able assistance of Miss Doris M. Cochran, and for aid in the bibliographic work upon the insects I am greatly indebted to Miss Frances M. Appleby.

April 16, 1925 AUSTIN H. CLARK

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BIOLOGY AND HUMAN WELFARE

To be able to live in comfort a man must have a special knowledge of some trade or profession; but to be able to live at all he must have at least some acquaintance with the subject of biology.

As commonly defined, biology is the study of life; but as contemplated by the average individual it is the study of disease and death and how to avoid them, and also how to inflict them on other hostile living things with the minimum of danger to himself.

Everyone is familiar with the trapping and poisoning of rats and mice, with the spraying of orchards to keep down the insect pests; with the boiling and sealing of fruits and vegetables to sterilize them; with the chlorinating of water to eliminate dangerous "germs"; and with the taking of quinine to cure malaria. All housewives recognize the clothes moths and the "buffalo bugs," and no lady is so tender hearted as to let one of these escape if she can catch it. Every country boy avoids the poison ivy and the poison sumach, and the nests of hornets, wasps and bees. All of this is but applied biology, mostly learned by the wasteful method of repeated experience, with behind it a long history of loss by destruction of crops and other property, and of discomfort, sickness and death.

Together with a greater or lesser number of biological facts the average person acquires a corresponding number of biological myths, more or less fantastic and usually harmless, but sometimes proving hurtful.

Let us illustrate the biological contacts of our daily lives with a concrete example. A small boy rises early and goes fishing. He puts on his cotton shirt and a pair of old woollen trousers, which he fastens with a leather belt. From the pantry he gets an egg, and while this is boiling he toasts some bread. Opening the door he finds that the milk has come and, knowing that he will be far away before his mother awakes, he helps himself rather liberally. The buttered toast, the egg and milk consumed, he hurries to the garden for some worms, but only finds a few. Thinking of the milk and of his mother, he decides to supplement the worms with grasshoppers and, taking his bamboo pole and a silk line, a present from a last year's summer boarder, he starts off for the river.

Under the eaves on the left side of the house is a "yellow-jackets'" nest, with the inhabitants already passing in and out; on the right is mother's window; so he goes past the hen house through the back fence, avoiding a post verdant with poison ivy, and continues toward the river, passing a "ground yellow-jackets'" nest under a large stone and a bumble-bees' nest in the sod further on. Near the river he turns off the path and catches sufficient grasshoppers to supplement his supply of worms. A garter snake which he sees he mashes with a rock. Reaching the river bank he trots barefooted across the mud to a convenient log on which he sits. Horse-stingers or snake-doctors are all about, and a very large one reminds him that it would sew his mouth up if given the opportunity.

Impaling a worm upon his hook he spits upon it after the most approved method and casts it in the water. Some minutes later the float moves slightly, then is still. Many minutes pass; he pulls the line up and finds the bait is gone. A painted turtle was the thief, but he does not know it. Another precious worm is now impaled. Upon this he spits from the other side of his mouth according to the plan successfully adopted by his cousin Jimmy yesterday. This time there are no results at all; the worm grows water-logged and mushy,

and he decides to try his luck elsewhere, a decision hastened by the numerous mosquitoes in this shaded spot. Passing a sandy shore he sees a large bass move hastily away. Here he at once seats himself on a stone and throws his line out near some lily pads. It is sunny and hot and still and the horse flies and the sand flies pester him; but if he can only catch that bass his mother will perhaps forgive him for the milk. Three of those small fish called pumpkin seeds and two small yellow perch eventually reward his efforts, but in catching them he loses both his hooks.

He now remembers that he had promised dad to spend the day searching for caterpillars on the tomato plants, for which the reward was to have been two cents a dozen; he also remembers other things, for instance, dinner time is twelve and it is now three. Slowly he rises, to see the bass dart off again, and gingerly collects his fish now encompassed with flies and a few hornets.

His welcome home is quite as he expected. His mother did not mind the milk, but when he left the house he wedged the screen door open in order to get out his precious pole, and the house is full of flies. However, mother soon forgives him, lunch revives him, and the tomato patch yields many worms before dad returns.

Now what are the biological contacts of Willie's day a-fishing?

Willie's woollen trousers were made from the wool of sheep from England. For centuries the ancestors of these sheep had been carefully selected in order to produce a strain that would yield the longest and most abundant wool instead of long hair mixed with short wool, the natural covering of sheep.

The breeding of animals is by no means a simple matter. In the old days long continued more or less haphazard efforts were attended eventually by more or less success. Recently, however, the subject has been studied in great detail and certain laws determined by the application of which desired results may be obtained, or at least approximated, with a

PLATE I

I. A BRAZILIAN TAPIR.

II. A WART HOG.

For detailed explanations of the figures see p. ix.

minimum waste of time and money. These laws of heredity were worked out not on sheep but on other animals, especially flies, of which many generations each with very numerous individuals may be obtained within a single year. But the broader generalizations discovered through the breeding of flies in the laboratory were found to be applicable to sheep on the farm, and by approaching the subject in this way enormous amounts of money were saved and, besides, many things were learned which could never have been learned from sheep. Similarly the generalizations were applied to the breeding of chickens to produce varieties which would yield the greatest number of eggs; to cattle to produce the largest yield of milk and butter; to wheat to produce the best flour; to silkworms to produce the best silk; and to other animals and plants to increase their value to us.

Living in large herds sheep and cattle are especially subject to parasites and diseases which must be carefully studied in order that their ravages may be prevented. Of these diseases we shall mention only one, at the same time cautioning the reader to remember that there are many others, some much less well known. The "liver rot" of sheep is widely spread and often disastrous, killing, it is said, not less than a million sheep a year in the United Kingdom alone. This disease is the evidence of the activity of a flat-worm or fluke, only one of several hundred kinds of these creatures, which lives in the sheep's liver. Each fluke produces half a million or more eggs which pass out of the sheep and fall to the ground. The rain washes them into pools and ponds where they hatch, giving forth an active conical creature, exceedingly small, which swims about until it finds a snail into which it bores its way. Failing the discovery of a snail it perishes; but unfortunately nature provides plenty of snails for it. Within the snail it grows into a sort of sac which in its interior develops another type of young; within these last more young develop, some like the parent, and some like minute pollywogs which emerge from the snail and swim away, climb up a grass blade, lose their

tails, and become inert. If a sheep eats grass with these things clinging to it they come to life again, plod their way to the sheep's liver, and soon develop into full grown liver flukes. The cost of wool production, and hence the price of woollen cloth, has been greatly lessened by the discovery of the intricate life history of this pernicious organism as a result of which means have been devised for controlling it.

The small holes in Willie's trousers just above the knee were made by buffalo bugs which concentrated on some spots of soup that Willie spilled one day. The lines nearby were made by clothes moths. Before this summer these trousers had been Willie's best, but they had been put away with insufficient care. The thread used in sewing the trousers was made from Sea Island cotton, a special type of cotton developed by many years of the most careful selection and grown with every precaution to guard it against insect and fungus pests each one of which had to be studied separately and exhaustively and traced in all its stages to determine how best it could be attacked. The buttons were attached with linen thread made from flax from Flanders, grown with the same care as the cotton and prepared on lines determined by long years of investigation as the best.

Willie's shirt was made from upland cotton, quite different from Sea Island, just as carefully selected, and just as carefully protected from the pests, but with different ends in view. Its sole remaining button, of white and shining pearl, came from a river mussel in Iowa. When young these river mussels attach themselves to fish and this is how these clumsy creatures mainly get about. This simple biological observation is of the greatest importance to the mussel industry.

Willie doubtless did not appreciate the dangers of the mud he walked across with his bare feet, for on mud lurk the young of the dreaded hookworms which bore through the skin and, entering the body, live within it and more or less seriously incapacitate the victim. In the copper-head which lay beneath the log on which he sat, unknown to him, Willie would

have seen an enemy at once. Yet ten to one its bite would have been less serious to him than an attack of hookworms. So, too, some of the mosquitoes in the shaded spot where first he fished were more dangerous than the copper-head, for within them were malarial organisms. Had these bitten him he might have had a most distressing and protracted illness.

The numerous flies which came into the house when Willie left the screen door open were mostly bred as maggots in the stable, and in a dead rat in the field. The common house-flies are well known now to be the carriers and distributors of various diseases, especially of typhoid fever. See them on those blueberry pies; who can tell what germs their little feet are leaving as they walk across the crust?

A fly bites Willie's father on the ankle and folding a newspaper, he proceeds to smash the flies upon the kitchen table. He does not realize that it was not one of these that bit him, but a very different sort of the same size and color but with a strong beak, a so-called stable-fly. He kills a small fly on the window pane. Though small now it would soon grow into a big one, in his opinion. He is wrong again; after flies transform from maggots into flies they grow no more. The little fly was probably of quite a different sort of which the maggots sometimes live in man producing great discomfort. But, again, it may have been one of those little flies that live when young as maggots in our rugs and carpets feeding on the clothes moths.

His wrath against the flies abated by the slaughter of some dozens of them, he picks up a small package of meat delivered by the butcher's boy some time ago. With a startled buzzing several flies escape and make for the window. The meat shows several clusters of light yellow eggs and some small maggots wandering about. These are the eggs and young of flies from some dead creature. One of the flies was caught and crushed between the paper and the meat as he picked the package up, a bluish one with three black lines between the wings. It came from a sore on one of the neighbor's cows

PLATE II

III. A Solenodon, and a Collared Peccary.

IV. A Great Anteater.

For detailed explanations of the figures see p. ix.

which will not heal. It is a screw-worm fly and its young will eat dead or living flesh, and it sometimes attacks man.

The worms on the tomato plants are the caterpillars of a large and handsome moth, the five-spotted sphinx, which in the spring at dusk visits the rhododendrons on the lawn. The large black butterflies which come to the nasturtium flowers lived as caterpillars on the parsley patch, while the caterpillars of the several small white ones in the garden are busy boring into cabbages.

But why continue further this catalogue of facts? Is it not clear that every living thing that Willie sees, and even more too small for him to notice, have each and all some bearing on his welfare? All plants are either useful, in providing food for man and his domestic animals, in furnishing fibers for cloth and cordage, in producing timber, or in yielding drugs or dyes; ornamental plants and shade trees have their value, too; or they are harmful in destroying useful plants, both through direct attack like rusts and blights, and by the prevention of their growth like weeds, or in occupying space in which more useful plants might grow; some of course, are very poisonous. Likewise all animals are either of benefit or detriment to man. The latter eat the useful plants or live as parasites upon or within man and the domestic animals or spread disease. The former serve as food or destroy the detrimental plants or creatures or serve to pollinate many flowers incapable of fertilization otherwise. Many insects, strange as it may seem, are detrimental when young, useful as adults, or vice versa, or sometimes useful, sometimes detrimental.

Let us briefly note the things that are not so, the myths, in Willie's concept of biology. Though all the evidence seems against the statement, human saliva does not add to the attractiveness of worms whether expelled from the right or left side of the mouth, or from the center. All snakes are carnivorous, eating other vertebrates or insects. They are highly beneficial to the farmer, and Willie saved the lives of many harmful creatures by squashing that garter snake. The

menace to health represented by the rattlers, moccasins and copper-heads of course largely offsets their value, but all the non-poisonous snakes are distinctly beneficial.

There is a widely spread belief that horses harbor in their insides snakes which are occasionally expelled. These squirming things are not snakes, but large unjointed worms called nematodes very commonly infesting horses as well as pigs and other animals, and man.

Dragon-flies eat only other insects which they catch upon the wing. They do not sting horses, nor do they doctor snakes. When young they live submerged in streams and ponds eating insects as they do when fully grown. Sometimes the larvae of the large ones eat small fish, but not unless severely pressed by hunger. In this country they are termed the "devil's darning needles" and with this name comes the idea that they can sew.

Some bees that Willie thought he saw on a dead animal were not bees at all, but bee-flies, the young of which sometimes live in carcasses. In ancient times it was supposed that bees were formed spontaneously from dead animals, these flies being mistaken for the honey bees. No living things of any sort ever appear spontaneously. All living things are the children of similar living things. All flies for instance, arise from maggots which come out of eggs laid by parent flies. All cases of malaria or of typhoid arise through transfer of the "germs" from other cases. This rule has no exceptions.

In the country you will sometimes hear that bumble-bees eat honey bees, and even wasps. The bumble-bees do no such thing; but there is a large asilid fly, very stout and colored like a bumble-bee, which has this habit.

These few examples serve to illustrate some common misconceptions, out of hundreds. A few of these are curious and harmful. In parts of Europe it is thought that to be healthy one must harbor cooties. The logic is that when one dies his cooties leave him; therefore coöties must be a sign of health. Now cooties carry typhus fever and are the cause of other sicknesses as well. But when a man believes his health depends on having cooties, what can a doctor do?

ANIMAL NAMES

A COMMON cause of misconceptions in zoölogy is the use in ordinary speech of a single name for several different sorts of living things.

We have in English numerous popular and familiar terms covering familiar creatures. Wherever Englishmen have gone they have carried these terms with them and, as best they could, applied them to the birds and beasts of other lands. Other races have done the same, and not infrequently their names have been adopted into English with very varied meanings.

Robins, wrens, blackbirds and orioles are found almost everywhere that Englishmen have settled. But the English robin is a very different bird from what we call a robin, while the robin of the West Indies is a sparrow. Some of our wrens are closely related to the English wrens, but the wren of the West Indies is a sort of thrush; there the true wrens are known as God-birds. The English blackbird is, except in color, very like our robin, with much the same habits and a very similar song. Our blackbirds are of a very different type, related to our orioles which have nothing in common, except the black and yellow color, with the old world orioles.

In the same way our New England hedge-hog is not at all a hedge-hog, but a porcupine, a rodent instead of an insectivore; our buffaloes are not buffaloes at all, but bison; our elk are very different from the European elk, which are like our moose. Again, our wild-cats are not true wild-cats, which have long tails and look much like domestic cats, but lynxes.

Trout is a very favorite name for fish. Our brook trout is a charr and not a trout. Our sea-trout in the south is a kind

PLATE III

V. A Two-toed Sloth, and a Hairy Armadillo.

VI. A Tasmanian Devil, and an Australian Spiny Anteater.

VII. Hawaiian Geese.

For detailed explanations of the figures see p. ix.

of weak-fish and in no way related to the trouts. The trout of the West Indian streams is a sort of mullet.

Silver-fish, jelly-fish, star-fish, etc., have of course nothing to do with fishes.

Jigger is the name applied to a kind of flea which burrows in the skin. But with us the term is usually bestowed upon a mite which further south is called bête-rouge or red-bug, though it is not a bug at all.

The name bee-fly is given to quite a lot of flies of different groups which look like bees or live with bees. Deer-flies are of two main types, deer-flies proper, related to the horse-flies, and the larger black-flies.

May-flies, stone-flies, alder-flies, dragon-flies, lace-winged flies, green-flies, saw-flies, scorpion-flies, butterflies, and many other kinds of "flies" have nothing at all to do with the true flies. In the same way June bugs and potato-bugs are not bugs but beetles; black-beetles are cockroaches, not beetles, and so it goes.

Any creature that even most distantly suggests radiation from a central point, even by merely running equally well in any direction, is in danger of being called a spider or a scorpion. The "Spider ground" near Provincetown is famous for the abundance on it of sea-spiders, sometimes called sea-scorpions, which in this case are basket-stars, related to the brittle-stars and other star-fishes. Elsewhere the terms sea-spider and sea-scorpion are used for pycnogonids, for crinoids, and for various other creatures.

The term worm is applied to anything long and soft and legless or with inconspicuous legs, quite regardless of its zoölogical affinities. Thus blind-worms are a sort of legless lizard; tongue-worms are a kind of enormous mite, related to the spiders; cabbage-worms are the young of butterflies; apple-worms are the young of moths; chestnut-worms and acorn-worms are the young of beetles; vinegar-worms, hookworms, pin-worms, Guinea-worms, etc., are nematodes; tape-worms are a sort of flat-worm. Most sea-worms are jointed worms

or annelids, related to the earth-worms, but strap-worms are nemerteans and ship-worms are molluscs with a pair of very minute shells modified for boring purposes.

We have adopted the Spanish word mosquito for the insects called in England gnats, a term applied by us mostly to chironomids, fungus-gnats and other little flies, and sometimes to male mosquitoes, though never to the biting females. But in some places where mosquitoes have another designation our name for them is used for sand-flies.

These few examples show the difficulties in the way of a proper understanding of zoölogy when explained in English terms, especially outside of England. Many efforts have been made to bring our common speech into accord with scientific knowledge. Such efforts have never been attended with very marked success and I believe are bound to fail for the reason that language is primarily the medium of exchange for ordinary thoughts and ideas relating to everyday existence. Groups of men engaged in restricted lines of work develop special words and phrases to convey an exact meaning to others engaged in the same line, but these never come into very widespread use.

And so robin and oriole, bug, fly, fish, etc., will continue to be misapplied except by those few with a deep interest in nature as long as English lasts, and the student of zoölogy must continue to beware the pitfalls hidden in the colloquial names of animals and must search out the explanation of the numerous discrepancies in the standard works of reference.

HUMAN FOODS

Let us investigate more fully our contacts with the animals. These fall under three main headings. We use animals and animal products as food; animals use us as food; and we make use of animals to transport us and to provide power, to furnish us with leather, silk, bone, horn, ivory, shell, perfumes, glue, dyes, medicines, and very many other things, which enter into our everyday existence.

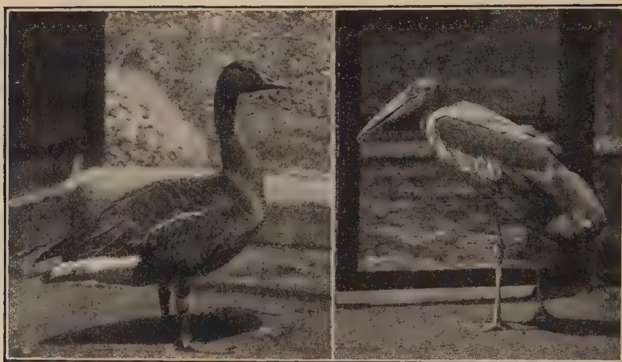
Fastidiousness is an attribute rapidly aquired by all peoples with increasing prosperity, and one of the first symptoms of an incipient attack is restriction in the number of different kinds of foods consumed.

In the Mediterranean there are some small and very inferior fishes allied to the perch (*Maena*) which no one will eat if he can possibly get anything else. In Venice, if you wish to say something especially mean about any one you say "Mangia menole," he eats these worthless fishes.

In America we do differently; we contemptuously call the Frenchman Froggy, and our sailors call the English Lime-juicers; and then we take the sting off by serving both frogs'-legs and lime juice in all our best hotels. And while we are enjoying a dish of "mountain oysters," served at a very high price, at the same time we pity the poor European peasant who eats snails.

In America we have always had abundant food; we have been able to pick and choose our diet, and many items have been eliminated from our list of edibles which are important economic factors elsewhere. Thus of the mammals, cattle, sheep and hogs are the only ones we use on a large scale, disregarding dogs, cats, rats, and many others which are freely eaten elsewhere, cats and rats when cooked being frequently

PLATE IV



VIII. THE BEAN GOOSE AND THE MARIBOU STORK.

X. THE HARPY EAGLE AND THE CALIFORNIAN CONDOR.

IX. THE DOUBLE YELLOW-HEAD.

For detailed explanations of the figures see p. ix.

called rabbits. Of birds we use chickens, ducks and geese, with sometimes a few others, like turkeys, guinea-fowl and pigeons, as special delicacies. Of our very numerous sorts of fishes only about half a dozen are widely used, with many others eaten locally; but in any one town one rarely sees more than a half a dozen kinds in the fish markets. Lobsters and the larger crabs, shrimps, oysters, clams and scallops round out our bill of fare so far as it concerns the animals. But let us see what other people eat.

While man regards without prejudice so to speak, almost all sea creatures and is perfectly willing to eat any of them if only they are not offensive to his palate, it is quite different with regard to animal life on land. For instance sentiment against snakes is so widespread that they are not usually used as food if this can be avoided, though they are eaten in some places, even in this country, and they are good to eat as I can testify. Monkeys also are not generally eaten except in parts of South America; but besides the protecting sentiment against their use as food their flesh is tough and strong, and there is little temptation to eat monkey twice.

Nearly all the larger mammals are eaten in their native countries, the exceptions being those that are so very tough, like many cats, or so very strong, as old he-goats, as to make this impracticable. Hoofed animals always are preferred to others. They usually are large and hence provide a large amount of meat which rarely has a disagreeable flavor. They live in open country or in open woods, never climb the trees, seldom burrow, and are usually more or less sociable in habit. They can therefore be secured in adequate quantities with a minimum of difficulty and of danger, and besides many of them are easily domesticated.

Burrowing animals when large enough are always popular as food, since they can be trapped or dug from their burrows with little expenditure of labor. But all the larger burrowing animals are rather scarce and solitary.

In the South American forests where hoofed animals are

few in kinds and scarce or, like the peccaries, rather dangerous, more different sorts of mammals are regularly consumed as food than elsewhere. The tapirs, peccaries and deer are favorites; but the anteaters, sloths, monkeys, pumas, porcupines and armadillos, as well as other kinds are also eaten.

In our own country, besides the various hoofed animals, bears, opossums, wild hares and rabbits, muskrats, porcupines, and even skunks are eaten, the last three much less now than formerly. In some places in the East the large fruit bats are esteemed as food; but most people find their flesh too strong.

Chicken and rice three times a day for six whole weeks once formed my bill of fare. Then we caught a whale and I acquired forty pounds of good fresh meat. Under the circumstances, perhaps, my judgment might be questioned; but I still look back on that whale meat as the finest meat I ever tasted, resembling the best of beef, but much more tender. I had no ice, and this was in the tropics, so in a day or two the flavor of whale oil was noticeable. This was corrected by some curry powder; but in a few days more it got to be too strong for any remedy, and I gave it to the natives, it being then in just the state in which they most prefer it.

All the whales are excellent as food, but the irregular supply prevents the widespread use of whale meat, though we sometimes find it in our restaurants, and one can often buy it canned. The larger whales are much like tender beef, but the porpoises and dolphins which eat fish have a more or less marked fishy flavor. In Greenland whale skin takes the place of chewing-gum.

Seals are used as food in many places, and their tongues especially are prized, as are the tongues of whales.

Sea-cows or manatees and dugongs are highly prized as food wherever they are found, but they are fast becoming rare. The largest of them, which lived in the Commander Islands, for some time has been extinct.

Nearly all kinds of birds are eaten if large enough to make it worth one's while or obtainable in sufficient quantities,

unless their flesh is nauseating, as in the vultures, or too bitter to be swallowed, as in the spruce grouse. I tried to eat some of the latter once in the White Mountains, but I could not do it.

Hawks are considered a great delicacy in some places, herons and parrots in others; but generally speaking it is the gallinaceous birds like the turkeys, partridges, quail, grouse and pheasants and their allies, and the numerous ducks and geese that are universally preferred. These are nearly all large, or at least fairly large, nearly all have excellent flesh, and most of them are sociable, so that abundant food is furnished by them with a minimum of effort. Many are readily tamed. Where they are common pigeons and doves are much sought after.

Where larger birds are scarce, as in the south of Europe, the little birds, like thrushes, warblers, and other passerines, are captured in large quantities with bird-lime, nets and snares. I have even seen the English sparrow in our markets, and in days past our fathers used to feast on robin pies. The great black crab-hawk on St. Vincent is a favorite among the natives, as is the local chicken-hawk. In the West Indies also the yellow-crowned night heron which feeds on crabs is much esteemed and very good.

Parrots are excellent when young, reminding one of squabs; when old, however, they are very tough. Young macaws are very fine; but the mastication of a fully grown macaw requires the jaws almost of a Hercules, combined with the patience of a Job. If other edible birds can be obtained, and this can usually be done, it is just as well to let the parrot tribe alone as parrots are hard to kill and wounded parrots bite most savagely. We generally avoid birds reeking with fish oil, like the large gulls, pelicans and fish eating ducks, though we sometimes eat the last when specially prepared. The very flavor we dislike so much recommends these bird to other races.

Some of the larger lizards, especially the iguanas, are de-

licious, and in high favor wherever they occur. That curious lizard known as the "chuck-walla" which is slightly less in size than the Gila monster and feeds on buds and flowers is much prized by our western Indians as food.

The flesh of the common crocodile in Africa is eaten by the natives there; but Sir Samuel Baker says "nothing can be more disgusting than crocodile flesh. I have eaten almost everything, but although I have tasted crocodile, I could never succeed in swallowing it. The combined flavor of bad fish, rotten flesh, and musk is the *carte de diner* offered to the epicure." Of the alligator the tail is considered a delicacy by the southern negroes, while one of the native crocodiles of Siam regularly appears as food in the markets of that country. Turtles and tortoises of all kinds and sizes are in general much prized, with the exception of the carnivorous sea turtles. We ourselves are immensely fond of the vegetarian sea turtles, served especially as soup, and of what we believe to be, and often is, the salt marsh tortoise or terrapin, paying for both a very fancy price. Our common snapper is very widely used as food, and of late years has decreased in numbers, especially near the larger cities. In the Balkans the little mud turtles of the ponds are considered a great delicacy, and small pond and river turtles are eaten elsewhere. The eggs of the large sea turtles and of the iguanas are much sought after.

Frogs in many places are esteemed a delicacy. Usually only the hind legs are eaten, but in some places they are boiled whole and consumed like buns. In Dominica one can sometimes see a native going home at night with a few "mountain chickens" — large frogs — attached securely to his person by passing the long hind legs beneath his belt. The giant salamander is eaten in the East, but so far as I know these creatures are not eaten elsewhere.

The number of food fishes is enormous, including nearly every sort of fish large enough to eat. A few fishes are poisonous, some are likely to cause illness, and some are shunned because they look poisonous, or merely because they are not

so sleek and handsome as we think a fish ought to be. As a rule we have a prejudice against eating sharks or skates, cusk or sea-cats, sculpins and fishing-frogs, all of which, however, are relished by less squeamish peoples.

The sea-pike or sea-gar is eaten in most places, but shunned in others because its bones are green and not white as fish bones ought to be. In the West Indies there is a persistent tale about a rat which was once seen to eat these green bones and shortly after observed to die in agony. But in one village in these islands you may hear this distressing tale about the rat and in a neighboring community you may find this fish, green bones and all, particularly esteemed.

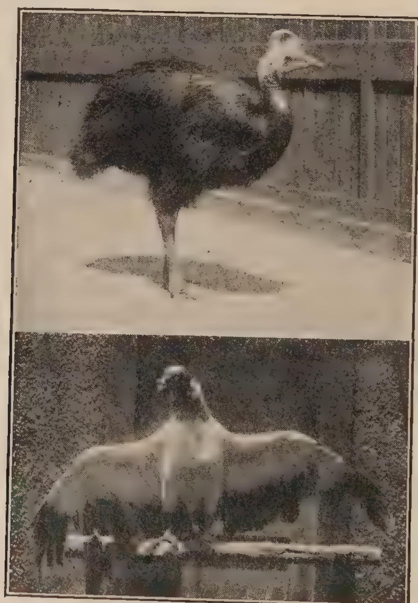
In the far north, especially in Greenland, the natives eat the flesh of the great arctic shark which they catch through holes in the ice near which it lurks in order to waylay the seals as they come up to breathe. If eaten as the flesh of other fish, and of other sharks, is eaten the arctic shark is very poisonous, both to men and dogs, causing what is known as shark intoxication. But after cooking in several changes of water the flesh of this shark is quite as harmless as that of any other fish.

As a rule when we eat a fish we leave the head, along with the back bone, for our friend the cat, the exceptions to this rule being mostly of an involuntary nature. Of a large fish we sometimes eat the tongue or cheeks, but our interest in the front end of a fish never goes much further. In many places, as in parts of the West Indies, the eyes are considered the most delicious part and are always eaten first, as I have often noticed; and in parts of northeastern Asia boiled salmon eyes are a favorite dish, looking like large blueberries. Sheeps' eyes are also very popular in Asia Minor.

Our fish we always cook, but in many places fish are eaten raw with or without a special kind of sauce. I have eaten raw fish in Washington as well as in Japan, and it is astonishing how good it is. But do not try to eat raw fish unless you know what kinds are safe to eat, for in some are found

PLATE V

XI. The African Black Vulture, and the South American Condor.



XII. A Cassowary, and a King Vulture.

For detailed explanations of the figures see pp. ix, x.

the dormant younger stages of certain parasites which, when the fish are eaten by the birds or seals, come to life again and grow to their full size in them. In the Baltic region and in parts of Asia infection of man in this manner is not rare.

Let us now consider the humbler animals without backbones that serve as human food. Any one familiar with the animals along our shores must have noticed the strange creatures called sea-urchins or sea-eggs, the star-fishes, and the sea-cucumbers.

Wherever sea-urchins are common they are greatly prized as food; they are eaten by the Indians in the northwest and on the Alaskan coast, in southern Patagonia, in the West Indies, especially at Barbados, and in the Mediterranean region. They are taken at the spawning season, and it is the eggs that are eaten. These are very good, either cooked in various ways or raw. When I was in the West Indies I frequently depended upon these things for lunch, bringing in a dozen or two from the reef and then breaking them open and scooping out the contents. In the Bering Sea the sailors on the "Albatross" became very fond of them and would look for them in the dredge as it came up.

The local value of the sea-eggs is sometimes quite considerable. For instance when I was in Barbados the fine for taking them from the water out of season was five pounds sterling. At the time I had a valet to whom I paid one shilling weekly. Had he misbehaved himself in this respect it would have taken nearly two years' salary to pay his fine.

The commercial value of the sea-cucumbers in the Pacific, where they pass under the name of trepang or bêche-de-mer, runs into the millions annually, but elsewhere they are not used to any great extent. They are eaten at Naples and at other places in the Mediterranean region, but only by the lowest classes. In America they are not regularly eaten anywhere, though in the West Indies they are gathered to some extent for the eastern markets. A few of the large star-fishes are sometimes eaten, but none are sufficiently abundant to be of great importance; besides, they are difficult to open, have

little in them, and that little is sometimes very bitter. That curious fish-like creature called in our text-books *Amphioxus* and supposed to be a primitive vertebrate is an important article of food in at least one town in China.

Swimming lazily in the summer sea the flabby jelly-fish are curious objects, and the more strikingly colored ones, red, purple or sky blue, are often very handsome. As we see them from the deck of a steamer or a yacht they may excite our interest, though never in the same way that it is aroused by the sound of the dinner-bell. Yet jelly-fishes are in various places an important article of food. In Japan a large kind is abundant in the Inland Sea which is caught in quantities and preserved with a mixture of alum and salt, or between the steamed leaves of a kind of oak. It is later soaked in water and flavored with condiments, and when so prepared constitutes an agreeable food. Other large jelly-fishes are eaten in the Philippines and elsewhere; and in order that we of European descent may not regard this as altogether an outlandish procedure I may mention that in Europe also jelly-fishes were eaten in the past, as far north as Cornwall in England.

Among the sea-worms there is one which is very important as an article of food in many places in Polynesia, called the palolo. When fully grown it averages about 16 inches in length and is sharply divided into a thick anterior part, about one quarter of its length, and a slender posterior part. In the slender hinder part the eggs are formed; and on or near the day of the last quarter of the moon in October and November the worm wriggles backward in its burrow in the coral rock or similar situation and breaks off the long hinder end, which rises to the surface and swims about, finally bursting and scattering the eggs. These swarming worm ends are considered a great delicacy by the natives and are gathered in great quantities. In Samoa and in Fiji this swarming is well known and has been carefully studied. The same or a similar worm occurs in the same way at other places, in the Gilbert and

Banks Islands, in the New Hebrides, on the east coast of New Ireland, and at Amboina. Throughout the Pacific Islands the spring season is recognized as the period of ripeness of the palolo, and wherever it occurs the season and even the months are named for it. In southern Florida the swarming of a closely related worm occurs within three days of the day of the last quarter of the moon between June 29 and July 28, though the worm is not here used for food.

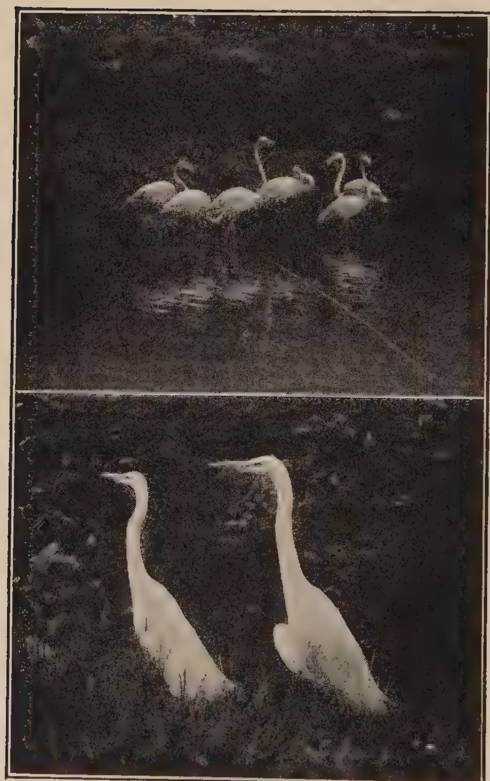
I suppose that none of the fishermen on our more northern coasts to whom the sea-squirt or sea-peach is a very familiar object ever thought of eating one. In the Mediterranean countries, however, they are regularly found in the markets. The outside covering, which is tough and indigestible, resembling wood fibers, and indeed of practically the same chemical composition, is removed, and the inside, which resembles the yolk of an egg but has a somewhat bitter taste, is eaten either raw or sprinkled with flour and fried in oil. Other sea-squirts are eaten on the west coast of South America and in other regions; but there is little likelihood of this habit spreading.

The common sea-anemones or animal flowers which are often such striking objects in the tide pools on the shores look no more appetizing than their relatives the jelly-fishes, though they are of somewhat firmer texture. Some of them, like many jelly-fishes, sting most painfully. Yet all of them, after cooking, are good to eat — or perhaps I should say can be eaten. In the Mediterranean countries where they are much used by the poorer classes they are generally fried in oil.

Condiments are usually classed as food, so it may not be out of place here to remark that at Barbados in the West Indies the millepore, a sort of branching coral-like thing related to the sea-anemones, is known as the "sea-ginger" because of the strong pepper-like sensation resulting from its application to the tongue.

While the number of different molluscs that we eat is very limited, oysters, clams, scallops and a few others being the only ones commonly consumed, other peoples are not so par-

PLATE VI



XIII. European Flamingos, and American Egrets.

For detailed explanations of the figures see p. x.

ticular. Almost all bivalves, snails or other types, marine, fresh water or terrestrial, which are large enough or abundant enough to make it worth while to gather them are used. Generally speaking univalves are considered inferior to bivalves, though the abalone or Haliotis is a great favorite in the east and in California, and in the West Indies the large conch or lambi is very highly prized. Squids and octopus of various kinds are in much demand in many parts of the world, and the first named form the basis for an important industry both in the Mediterranean region and in the east, especially in the Sea of Japan. As I know from personal experience both are very good when properly prepared.

Lobsters, and crabs and shrimps of various sorts and sometimes cray-fish make up the list of crustaceans which we consider edible. Elsewhere many more kinds are eaten than with us, among the stranger forms the large barnacles and the eggs of the horse-shoe crabs.

When you go through a fish market in the eastern countries or in the Mediterranean region do not assume that everything exposed for sale is edible. The intention of the proprietor is to sell as much as he can; you are supposed to know the food value of your purchase. One often sees beautiful brittle-stars, queer star-fish, "tiger tusks" and other things displayed more by way of ornament than for any other purpose.

The prejudice accompanying increasing civilization operates to diminish the consumption of insects as food. We dislike to eat bugs, no matter how nutritious they may be. Other races, however, view the subject in quite a different light. The seventeen year locust, or periodical cicada, in the years of its abundance used to form an important article of food for the Indians, who usually ate them boiled. They were caught in great quantities as they emerged from the ground to transform into the winged state. The white settlers, imbued with the English prejudice against eating insects, never adopted this habit, though they found them very useful for boiling into soap.

The ancient Greeks thought so well of the song of the cicada

that these creatures were the favorites of every Greek poet from Homer and Hesiod to Anacreon and Theocritus. To be said to excel a cicada was the highest praise a singer could receive. The music of Plato's eloquence was said to be only comparable to the voice of a cicada. Cicadas meant quite as much to the Greeks as scarabs did to the ancient Egyptians, and golden cicadas were worn by the Greek women in their hair. But in spite of the veneration the Greeks had for the cicadas they fully appreciated their economic value and used them extensively as food, preferring them, like our Indians, just as they emerged from the ground. Cicadas of various sorts were eaten by the Romans, and they are still used for food in many places.

From the eastern foot-hills of the Rocky Mountains to the Cascades and from Oregon to Mexico there lives a rather large moth inconspicuously colored called the Pandora moth, the caterpillar of which lives on pine trees sometimes, at least in the north, in such numbers as completely to devour all the leaves. This is one of the longest lived of all the moths, as it lives for two years and not for a single year or less like nearly all the other moths and butterflies. The caterpillars are only about one-third grown when the winter overtakes them. They all climb to the top of the tree and there spin a silken nest, much as the tent caterpillar does in the spring, from which they emerge when the warm weather again sets in. By the next autumn they are fully grown, over two inches long and very fat. The Indians in the regions where they are abundant, for example the Pai-Utes in the Klamath region of Oregon, prize them very highly, collecting great quantities and drying them for winter use. These dried caterpillar mummies are shrivelled, dark red-brown, and oily, and have an interesting rather than an appetizing odor.

But it is seldom that moths or butterflies are regularly used for food not because of any distaste for them, but because the caterpillars and pupae unless small or covered with hairs or bristles are rarely obtainable in sufficient quantities to make

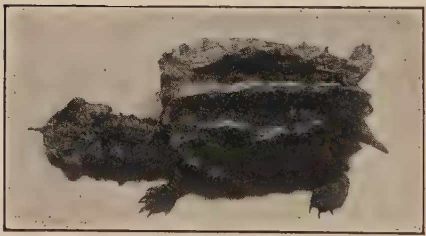
it worth while to gather them, and because the winged adults are so fuzzy as to fill the mouth with dust. Caterpillars of several kinds are eaten by the African bushmen, by the Australian natives, and by the Chinese. The caterpillar of the goat-moth used to be a favorite with the Romans. The Chinese and the Indian raisers of the Tussar silk moth eat the chrysalids after the silk has been unwound.

The "manna" of the ancients appears to be a term applied to several different foods of insect origin. The grub of a certain weevil which lives on acacia roots when about to transform into the adult climbs the stem and, finding a suitable position, surrounds itself with a thick froth which hardens into a white and snowy mass within which is the pupa. These white masses, with the pupae in them, still found in the markets of the near East, are probably the "manna" to which most frequent reference is made. But another sort, the secretion of a scale insect growing on the tamerisk in the same regions, is also there still used as food.

In many of the salt and alkaline ponds and lakes in our western country, from Washington to Mexico, there lives abundantly a small aquatic fly known as the *Ephydra*. When the maggot, which lives in submerged or very wet decaying vegetation, is fully grown — about half an inch in length — its outer skin hardens and turns brown, forming a protection for the included pupa, which shows through as a yellowish kernal like a small yellowish grain of rice. Mono Lake, California, is subject to violent winds in the latter part of the summer, and the disturbance of the lake loosens many of the puparia so that they float to the surface and wash ashore where they drift up in heaps, and hundreds of bushels may be collected. The Indians come from all around to gather them for food. They are dried in the sun, and the shell rubbed off by hand, leaving the small yellow rice-like pupae. These are oily, very nutritious, and not unpleasant to the taste. Until not so very long ago this fly formed an important article of food for the Indians in the regions where it is abundant.

PLATE VII

XIV. A Galapagos Tortoise.



XV. A Matamata Turtle, and a Gila Monster.

For detailed explanations of the figures see p. x.

There is another and very different fly called *Atherix* which is still more important as an article of food in the west. This fly, the maggot of which lives in streams, lays its eggs on the branches of the bushes and trees overhanging the water. Many will lay their eggs in the same place, hanging to each other in such numbers as to resemble a small compact swarm of bees. On the Pitt river in California the Indians are accustomed to place a line of logs across the stream, then go up-stream and shake the flies off the willow bushes. The masses of flies and eggs float down and lodge against the logs in great quantities so that as many as a hundred bushels may be gathered in a single day. The mixed masses of dead and living flies and eggs are then steamed and cooked in holes dug in the ground and heated with stones and thus prepared for winter use.

In tropical America there is a large black beetle, the palm weevil, the grub of which, called the "gru-gru worm," lives in palm tree tops. Wherever they are found gru-gru worms are a great delicacy. They are commonly eaten raw, especially by native children who regard them much as our children do candy; or they may be fried in their own fat and eaten on yams or potatoes. Consumed in either fashion they are very good, though somewhat tough. Beetle larvae, particularly the young of weevils and of rhinoceros beetles and cockchafers, relatives of our common June bugs, are frequently used as food in different parts of the world. During the war pickled beetle grubs even formed the *pièce de resistance* at a luncheon given in Washington. In parts of Europe, especially in Germany, adult beetles corresponding to our June bugs are often caught and eaten by children, and in Africa the very large beetles are roasted over a fire and greedily consumed.

The larger grasshoppers, called locusts, are a very favorite food. The Arabs eat them when they are abundant, ground up in hand mills as a substitute for flour, and also boiled or stewed in butter. The Hottentots feast upon them and make a coffee colored soup out of their eggs. In Calcutta

dried locusts form a part in the preparation of most delicious curries.

White ants are eaten generally by Hottentots and other Africans, raw, boiled, or parched in gentle heat, when they remind you of sweet almond paste. They are also eaten in the warm parts of America, and in India, especially their queens. True ants of various sorts are eaten. On the Amazons the saüba ant is captured by the basketful for food at the time of swarming and eaten raw. In India the spinning ants are used in curries and also crushed and used as smelling salts.

In Africa there is a small bird called the honey indicator which will guide you to the nearest bee-hive. The natives, after they have feasted on the contents of the hive, consuming a mixture of honey, grubs and pupae, always take care to leave enough so that the little guide shall be rewarded. In India the grubs and pupae, as well as the honey, of the large jungle bee are eaten.

In parts of Polynesia large centipedes are eaten, after being cooked over a fire while held firmly by both ends.

Large earth-worms on a smooth surface make a sort of tinkling sound with the rings of stout hooks which encircle their bodies and by means of which they crawl. While they are nowhere used as food, except, perhaps, occasionally in India, the singing girls of Java sometimes swallow them in the hope that the tinkling sound will in some way be imparted to their voices.

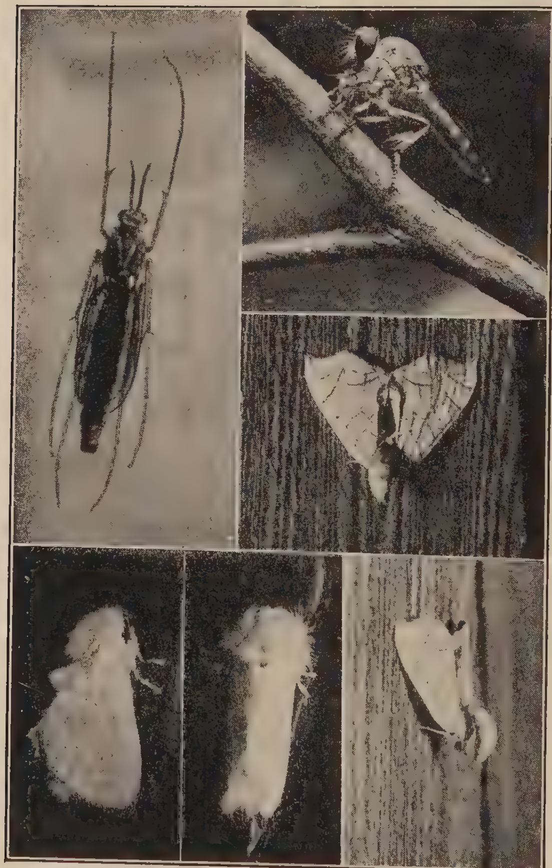
Perhaps it would be just as well not to pursue this topic further. Enough has been said to show that man as an animal is omnivorous. All nutritive non-poisonous plant and animal substances, together with many non-nutritive and others more or less poisonous, are consumed by him. As a human being, distinguished from the animals by the use of fire, his diet has become greatly modified in accordance with his habit of applying a high degree of heat to almost everything he eats.

MAN AS FOOD FOR ANIMALS

It is not likely that man ever formed an appreciable part of the food of any of the predaceous vertebrates. Tigers, jaguars and lions, and particularly wolves, when pressed by hunger will kill and eat men; but even in prehistoric times the danger from them probably was never very serious, and it is now almost a thing of the past. Each of these still capture an occasional victim, most frequently the wolves in winter, while the little mongoose sometimes nibbles off the ears of infants left sleeping by their mothers in the fields. Portions of the human body are occasionally bitten off by sharks, which are not nearly such terrible creatures as they look, though a few species and a few individuals of other species may be dangerous, as was shown off the New Jersey coast a few years ago. Large caymans, gavials and crocodiles pick up a few victims each year, but they are not regularly man eaters. The small cannibal fishes of the South American rivers are much more to be dreaded then these large reptiles, while in the sea the barracoudas are at least as dangerous as the sharks. But probably more men are killed by poisonous snakes in self defense each year than are killed for food by all the other vertebrates combined.

While the relatively large size of man renders him immune from the attacks of all but a few predaceous creatures, that very feature serves especially to recommend him to all such animals as are able to adapt themselves to live upon or in him. Four groups of insects include species which habitually and sometimes exclusively feed on man, the flies, fleas, bugs and lice, while other types as tree-hoppers, occasionally bite, and some ferocious ants will feed on human flesh as readily as on any other kind.

PLATE VIII



XVI. A Fungus Gnat, A Robber Fly, and two kinds of Moths.

For detailed explanations of the figures see p. x.

Let us first take up the flies, the most numerous, the most dangerous, and the most cruel of all our animal enemies.

The screw-worm fly, a rather pretty creature common in tropical America — abundant in some places — and occurring as far north as Canada, lives normally in carcasses, but frequently it lays its eggs in sores or cuts or in natural body cavities and the maggots radiate from these in all directions. In man the nose, ears and eyes are most affected. All the larger animals in regions where this fly is common are very liable to infection in scratches or other wounds. This fly is of a most persistent nature and sometimes commits suicide in an effort to reach suitable food for its young. When I was collecting birds in the West Indies I wrapped the skins in sheets of cotton wool. This is sufficient to keep out blow-flies; but the female screw-worm flies will bore their way into the cotton, finally becoming hopelessly entangled and dying almost on the flesh they tried so hard to reach.

There is a closely allied fly with similar habits in southern Asia, and another, less closely related, in Europe which is especially troublesome in Russia; both of these are said to attack only living animals. Many of the flesh flies occasionally breed in wounds or in natural cavities of the body, and these become a terrible curse to wounded soldiers in times of war when their numbers are vastly increased through breeding in unburied corpses. Those large, dark, hairy, rather slow and clumsy flies which commonly get into houses, and especially into cellars, and the smaller shiny green or coppery flies commonly seen sunning themselves on garbage cans are among the most pernicious of these. The common large gray dark striped flesh-fly also has this habit.

The larvae of the human bot-fly, which occurs from Mexico to Argentina and is a true bot-fly, live in swellings which they produce beneath the skin. Their method of entering the host is most remarkable. The female bot-fly captures a large female mosquito or other fly and glues her eggs to the under side of its abdomen. When the fly with the eggs attached

alights upon the human skin the maggots emerge and enter the puncture made by the mosquito. Various animals are also parasitized by this fly.

The warble-flies of cattle and the horse bot-flies sometimes live as maggots beneath the skin of man, and the larvae of the sheep bot-fly occasionally infest man, particularly the cavities of the head. In tropical Africa there are several flies related to the blow-flies of which the maggots live under the skin of man as well as under the skin of various animals. The best known of these is the tumbu fly.

There is one very interesting fly the maggots of which suck blood after the manner of the leeches. This is the adult of the Congo floor maggot, which occurs throughout tropical Africa. The maggots live in the dust and cracks of the floors of houses and come out at night to suck the blood of the sleeping inhabitants. It is not known to trouble any of the animals, but similar maggots live in the burrows of hairless mammals. Similar flies live in the nests of birds and suck blood from the nestlings.

The maggots of a considerable number of different flies if swallowed will live in the intestinal tract of man, but in the case of most of the species which have been recorded, infestation is rare and purely accidental. House-fly maggots occasionally enter the body and cause trouble. Much more common is infestation by the lesser house-fly and the cheese-skipper, which may lead to serious consequences. Bot-fly larvae and the larvae of the large gray flesh-fly have been found in man.

Strange as it may seem the worst of all man's enemies in the insect world are the mosquitoes, the commonest and most widely distributed of the blood-sucking flies. More than 500 species of these have been described, and many of these species under suitable conditions occur in absolutely incredible abundance. In the little island of Carriacou there is a musical swamp which at the proper season you can hear humming for a long distance. A road passes through this swamp, and as you approach you soon learn why it hums. On entering you

are enveloped in a mist of mosquitoes which trails out several feet behind, and your horse is almost hidden by them. I have never seen the equal of this swamp, at least as it was twenty years ago, but I have not the slightest doubt that there are many other places just as bad or even worse, in the north as well as in the tropics. In Alaska they sometimes drive the bears and deer into the water.

Though most are dull, some tropical mosquitoes are very brilliant in their coloring, burnished copper or iridescent green. In the mountains of St. Vincent I well remember a brilliant green mosquito that used to hunt me when I was hunting parrots.

The different species of mosquitoes vary greatly in their habits. When young most of them eat dead organic matter, some eat small microscopic creatures, while a few have predaceous habits. As adults a few feed entirely on the juice of plants while most of them will do so if they cannot get blood. I have seen numbers of them feeding on bananas. Male mosquitoes never bite. The females of some species will attack a large variety of vertebrates, including even turtles, while others are more particular, a few specializing to a large extent on man. One of our commonest mosquitoes in the eastern United States never bites man, but feeds on the blood of frogs and perhaps also on some other cold blooded animals.

As is now well and generally known the mosquitoes in the warmer regions are especially to be dreaded as carriers of disease; malaria, yellow fever, dengue and filariasis are spread by them, the causative organisms being injected while they bite. Mosquitoes also serve as disseminators of the human bot-fly.

In Africa the tsetse flies are easily first among the insect pests as the carriers of sleeping sickness and other trypanosome diseases. These flies resemble the bird flies in having no feeding larval stage, but feeding only as adults, as well as in being wholly parasitic on the vertebrates. As in many, if not most, bird flies the young are born full grown and ready

PLATE IX

XVII. A West Indian Fire-fly, and four kinds of Moths.

For detailed explanations of the figures see p. x.

for pupation. Since they feed only when adult, both sexes bite.

All biting insects that transmit disease do so only on the second and succeeding bites. From the pupae they emerge free of disease, which they acquire from first biting an infected animal. In many cases the disease germs pass through a special phase of their life history within the insects' bodies, and until this phase has been completed they are incapable of growing within a vertebrate, within which they pass through a different phase. In a few cases the transmission is mechanical, the disease organism being carried to the victim without undergoing any change within the insects' bodies, somewhat as a house-fly carries typhoid. Only in a tick (related to the spiders and not a true insect) are disease germs known to be transmitted from the mother to the young so that infection may result from the first bite.

It was in the late spring in the mountains of New Hampshire that I first became acquainted with the black-flies. These vicious things are small, but they have very painful bites and they occur sometimes in enormous numbers near the mountain streams in which their larvae live. Their adult life is short, however, and they do not bite at night. There are numerous species widely scattered over the world. They are not known to be carriers of disease, but their attacks are sometimes fatal. Only the females bite.

The tabanids, the well known horse-flies, deer-flies and their allies are for the most part much larger than the other biting flies and some are very large, an inch or so in length. Their bites are rather sharp and painful, but not poisonous, or at least not much so. About 2,500 different kinds have been described. The young live in water or in damp ground and are predaceous. Only the females bite, and they bite only in the daytime, and only in the open, never under roofs. The males of some species are quite different from the females, and remind one of syrphids in their habits. Some species are important as mechanical distributors of various animal

diseases, especially of anthrax, which sometimes attacks man. In Africa deer-flies act as carriers of a parasitic worm known as a loa which creeps under the human skin. When tabanids occur in great numbers, as many species often do, their attacks are sometimes fatal.

Often mistaken for the house-fly because of its similar size and color is the stable-fly which, like its various close relatives, has blood-sucking habits. This fly, unlike most other blood-sucking flies, prefers to bite through clothing, stockings particularly. Its maggots mostly feed in decomposing vegetable material, but sometimes breed in manure like house-flies. Both sexes bite, and they are able to transmit anthrax and probably other diseases.

The psychodid or phlebotomous flies, in the orient commonly called sand-flies, of many species, are small, but have a very painful bite. The larvae live in cracks and chinks feeding on vegetable material. Usually only the females bite. Some species disseminate phlebotomous or three days' fever, and they have been accused of carrying oriental sore and other illnesses.

The biting midges, the smallest of the biting flies, are known to everyone as sand-flies, punkies or no-see-ums. Though very small, their bite is quite annoying, and they often occur in numbers. The young live in water or in moist places, some in sea water. Only the females bite, mostly toward evening or in the early morning, and especially when the air is very still. On the island of Mayreau a few miles from St. Vincent I once constructed a duck blind on the shore of a shallow pond. But it was not possible to use this blind at all on account of the numbers of these flies which in the early morning and towards evening quite drove one frantic. Some of these flies have been supposed to carry a form of oriental sore.

The three species of lice or "cooties" which live exclusively on man each on a different part of the body have been much discussed in recent years. Typhus, trench fever and relapsing fever are carried by these insects, which possibly carry also other illnesses.

There are several hundred kinds of fleas, most of which are parasitic on the mammals, some on birds, one only on a snake. A number of these, especially the human, dog, cat, rat and squirrel fleas, are important as pests of man. Plague, as well as other diseases of more or less importance, is transmitted by certain of these insects.

Of the so-called bugs, the bed-bugs are best known as parasites of man. There are two widely distributed species, one in the tropics, the other in cooler regions, and a third in West Africa which specialize on man, though they will suck the blood of various mammals and even birds if no human being is available. Other closely related forms live on birds, bats, etc. Strangely enough these insects have not been definitely proved to transmit disease.

The assassin or reduviid bugs include a number of large and active insects ferocious in disposition and bloodthirsty in habits which frequently, or even habitually, prey upon man. These are especially numerous in the American tropics, extending northward into the southwestern and southern states, with a few in the northern states and some in Africa and Asia. Those which most frequently prey upon man are usually known as "big bed-bugs." While these "big bed-bugs" have an almost painless bite, the bite of nearly all the rest, which attack man only casually or accidentally, is very poisonous and painful. In the northeastern states the best known is the so-called "kissing-bug," a purplish black sort which bites very severely; but one or two others are much larger, the "wheel-bug," for instance, reaching an inch and a half in length. In South America some of these bugs transmit a serious disease caused by trypanosomes. There are quite a number of true bugs in other groups which will sometimes attack man. Nearly all the larger water bugs will bite severely if handled carelessly.

Passing now to the spiders and their allies, we find very many human parasites among the ticks and mites. All of the ticks are parasitic, mostly on mammals, but also on birds and reptiles, and many, both of the bird and mammal ticks, attack

man. Some have very painful bites, and some have been shown to transmit dangerous diseases. The mites are mostly small and many are almost invisible. Some are vegetarian or feed on decaying matter, while others are predaceous and many are parasitic. The most familiar are the "red-bugs," "jiggers" or "bêtes-rouges," so very annoying in the spring time in the south, and the itch-mites of various sorts. There are very many kinds of mites which attack man, even among plant-feeding types. One mite has been proved to transmit disease. Related to the mites but much larger are the curious tongue-worms which live in the lungs and air passages of carnivorous mammals and reptiles and when young are internal parasites. Both the adults and larvae are sometimes found in man; these usually are of a species from the dog, though they sometimes come from snakes.

Of the leeches the most important as human parasites are the land-leeches which are a miserable pest in many warm moist countries, and those small leeches which, taken in with water in the act of drinking, attach themselves to the lining of the mouth and nasal passages.

There are three types of so-called "worms" which habitually feed upon the human body or live on the results of its activities. The flat-worms or flukes are most remarkable creatures with a life history so complicated it is a marvel that any at all survive. In many cases the chances are more than a million to one against any single egg developing to maturity; and yet there are plenty of these creatures. The life history of one of the flukes has already been given in the introduction; in some the life history is still more complicated, involving three entirely different hosts. All of the flukes infesting man, over twenty kinds of blood flukes, liver flukes, lung flukes and intestinal flukes, are parasitic in fresh water snails at some stage of their development.

Everyone has heard of tapeworms. These are related to the flukes. They have a somewhat less complicated life history, though most of them live in one host in the earlier, and

in another in the later stages. There are numerous different kinds in man some of which are very long, up to 30 feet or more, and others very small, less than an inch. Most of them are also known as parasites in cattle, hogs, dogs, rats, mice or other animals, with the early stages in insects, crustaceans, fish, frogs, snakes, mammals, etc. Various larval tapeworms have been found in man of which the adults have not been determined. One larval tapeworm found in man is the young of a dog tapeworm; this would promptly develop in any dog if it ate the flesh of an infected man. Ordinarily dogs become infected from eating carcasses or offal from sheep and cattle which also harbor the larval worms.

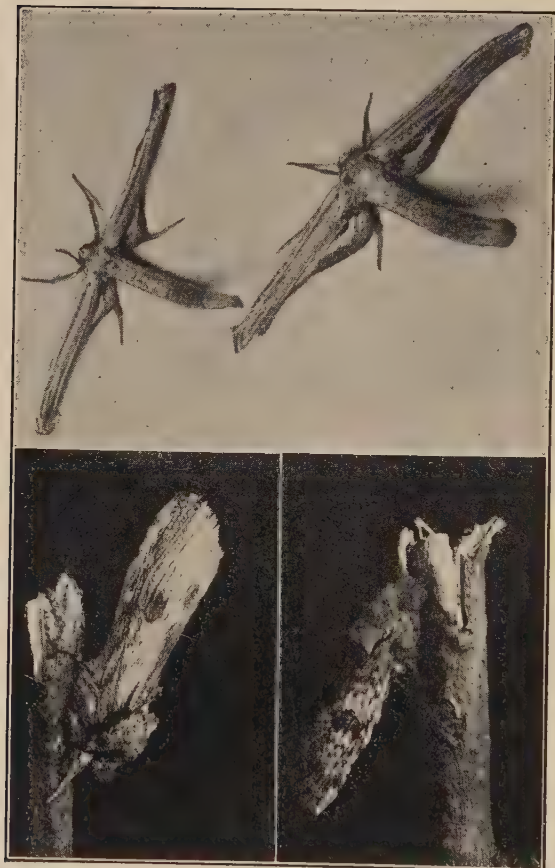
Of the extremely numerous sorts of round-worms 59 species are listed as having been found in man, some of which are dangerous parasites, some relatively harmless, and some merely casual or accidental.

The most important of the round-worms as human parasites and a terrible menace to health and efficiency in most of the warmer regions are two sorts of hookworms which live in the intestines and enter the body by boring through the skin, usually of the feet and legs. The eel-worm, which sometimes measures as much as 18 inches in length, is also a serious pest in many places, especially in children, as is the trichina which is contracted from eating uncooked or insufficiently cooked pork. The various filarial worms, some causing elephantiasis, so common in many tropical lands, belong to this group. They are transmitted by certain mosquitoes, tabanids, etc. The largest of the round-worms are the Guinea-worms which, from 3 to 5 feet in length, live beneath the skin. When young they live in those little water fleas called copepods.

A few sorts of the so-called spiny-headed worms sometimes occur in the intestinal tract of man.

Within the human intestines live quite a large number of different protozoans — amoebas, flagellates and ciliates — which under a microscope recall the similar forms occurring in hay infusions. These animals are able to form about themselves

PLATE X



XVIII. Three kinds of Moths.

For detailed explanations of the figures see p. x.

a firm membrane or shell within which they can resist dessication, often for long periods. Some of these internal protozoans, especially one species of amoeba, are injurious to health, and not infrequently their activities are attended with fatal results. Of the others some appear to be more or less injurious, and some quite harmless. Many of them live also in various animals.

Very interesting creatures are the so-called trypanosomes, and often very deadly, especially in Africa where they are the cause of that terrible scourge known as the sleeping sickness. These pass through part of their life history in the tsetse flies. Some of the American kinds are incubated by certain assassin bugs.

Of the protozoans which reproduce themselves by the formation of numerous spores, the so-called sporozoans, by far the most important are the several kinds of malarial organisms which live on the red corpuscles of the blood and are injected by the bite of certain species of mosquitoes. There are, however, various other sporozoan parasites in the human body which attack different tissues, some with often very serious consequences. Many of them are transmitted by lice, sandflies, ticks, mites, etc.

The numerous sorts of spirochaetes form a very interesting group of minute creatures. Some of these are free living, some commensals or mess mates with various molluscs, some harmless parasites of man and various animals, and some malignant parasites, the causative organisms of some of the most horrible of the diseases which infest man, as well as of many diseases of milder form and lesser importance.

MAN'S PLACE IN THE WEB OF LIFE

From this brief sketch of man as food for animals and of the animals as food for man we get a true idea of man's real place in nature. Man as a race consumes all things that can serve as food for him, while all types of creatures that can do so feed upon his body, which in its relation to the lower animals may be compared to a saline pond crammed with foodstuffs.

The contacts of the mammals, birds, etc., with the other groups of animals resembles in its general features that of man, though they are far more subject to attack, especially the smaller ones, by large predaceous creatures.

But man in addition makes use of very many animals for purposes other than the direct increase of his food supply. The powerful bodies of the horse, ox, camel, elephant, water-buffalo, llama, yak, dog, etc., assist him in his labors. The milk of cows, goats, sows and other animals yields butter, cheese and other products. The woolly covering of sheep gives him warm clothing, and the hair of beavers and of rabbits, felt. Fish yield glue, isinglass, and other things, and sea turtles tortoise-shell. The industry of bees gives him wax and honey. Various caterpillars of the larger moths are silk producers, and from other insects he gets dyes, varnishes and medicines. The list of animal products used by man, of which those given are but samples, is very long.

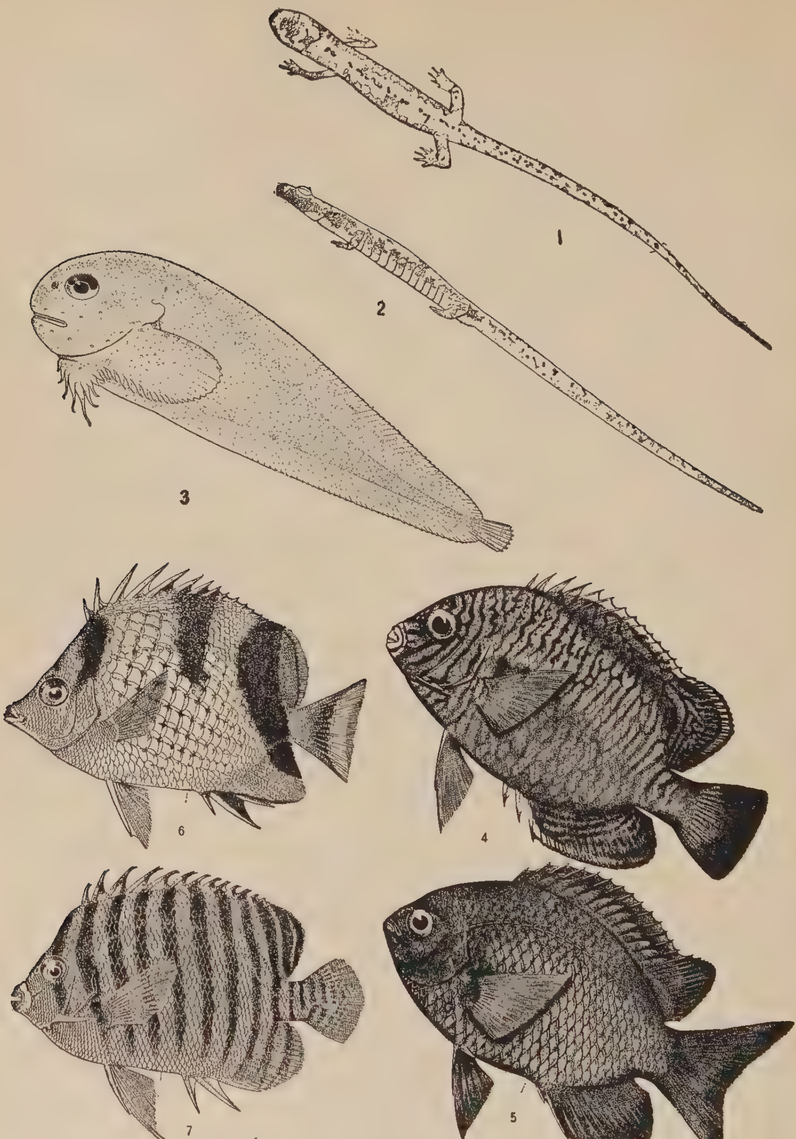
To a large extent man lives in an artificial world of his own creation. All the enemies of his domestic animals and cultivated plants are enemies of his just as truly as if they attacked his own body; their enemies are his friends; the enemies of the latter are again his enemies, and so on. The indirect relationships of man to animals are much more important than

the direct relationships, but they are so exceedingly complex that they can only be mentioned here.

There is one phase of the subject, however, that must be noticed. Man has often tried to assist nature for his own benefit with sometimes unforseen and more or less disastrous results. The mongoose was introduced into the West Indies to kill the rats, which were a serious problem in the cane fields. First a large gray mongoose was brought in which did not thrive, and later a small brown one which throve too well. The most noticeable result of this introduction of the mongoose was not a diminution in the numbers of the rats, but a marked decrease in the numbers of the small doves and other ground nesting birds and of the lizards, coupled with a great increase in the numbers of obnoxious insects. For instance on St. Lucia the screw-worm flies soon became abundant and a terrible pest to live stock. Why? Because these flies, which like to sun themselves on rocks and fence rails, fall an easy prey to the numerous small lizards which frequent just such situations, and the mongoose feeds largely upon these little lizards.

On the adjacent island of St. Vincent, fifteen miles away, two sorts of mole crickets promptly increased enormously. Mole crickets on St. Vincent are eaten by a large ground lizard which, noting the surface movements which they cause, runs to the spot and digs them up. The mongoose found the young of these ground lizards easy prey, resulting in the great increase in the mole crickets. But the increase in the mole crickets had been noticed by the local chicken hawk which previously had fed upon small lizards chiefly; and in 1903 I found these hawks to be the main consumers of the mole crickets.

The history of the introduction of rabbits into Australia, of the gypsy moth and brown-tail into New England, and of hosts of other cases, show the delicacy of the animal balance in the world in which we live and the complexity of man's contacts with it.



FIGS. 1–7. The cave Salamander, a Liparid, and four reef fishes.
For explanations of the figures see p. xi.

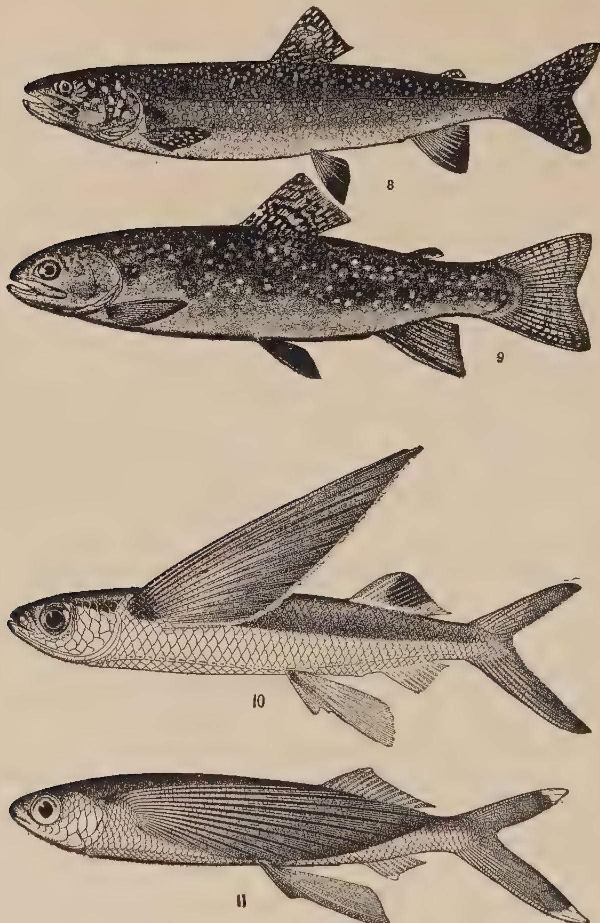
MAN'S CHIEF COMPETITORS, THE INSECTS

In the preceding pages frequent mention has been made of insects, those omnipresent little creatures that force themselves on your attention everywhere. The insects number about three-quarters of all known kinds of animals, and on the land and in fresh water are the most important of the living creatures; for not only are there half a million known, and many more unknown, but each of these half million kinds exists in countless numbers. To explain the conditions under which we live it is first necessary to present a brief account of the food relationships and some of the activities of insects.

We are accustomed to think of insects as feeding on vegetation or on each other, but in reality their feeding range is far beyond this; and if we include substances which insects chew, whether for food or for some purpose still unknown to us, there are few things which are free from their attacks.

In the first place, an enormous number live as larvae, and often also as adults, on green leaves, mostly by consuming them entire, but some by mining through the tissues. Such insects are nearly all the moths and butterflies, most grasshoppers, crickets and their allies, most saw-flies, many beetles, many flies, and many millepeds. While some of these will eat a large variety of plants, most are more or less restricted in their diet, and very many will eat only a single kind. All plants, no matter how poisonous they may be to us, have their insect depredators. Some of these are not at all affected by the poison, like many that feed upon *Euphorbias;* others cleverly avoid the portions where the poison lies.

The juices of plants sucked out through a tube from the leaves or stems or roots support aphids, scale insects, leafhoppers, cicadas, and many bugs.



FIGS. 8–11. The Lake Trout, the Brook Trout, and Two Flying-fishes.

For explanations of the figures see p. xi.

The flowers of plants, especially the ovary with the developing seeds, nourish the larvae of numerous beetles, flies and moths. Honey and pollen from flowers form the food of the young of most bees, some beetles, and a few flies and moths, and honey is eagerly consumed by the adults of many butterflies and moths and flies as well as beetles, wasps and other insects which as young live on leaves, as borers, in decaying matter, or even as carnivores or parasites.

As borers in the tender shoots or pith live the young of many flies, like the Hessian fly, various moths and beetles, and some saw-flies. As borers in the woody trunks of living trees live many beetles, horn-tails, some moths, and a few strange flies.

The tender roots of plants are devoured by many beetles, like the June bugs and their allies, by many moths, and by certain flies, as crane-flies, as well as by the mole-crickets and some millepeds which burrow for them underneath the ground. Young cicadas and some aphids suck the juices from them. The inner bark of trees nourishes a host of types, especially beetles and flies.

Fruits of most kinds are fed upon by the young of fruit-flies, at least in warm climates; moths and beetles bore into them to consume the contents of the seeds; various insects, including some adult moths, puncture them to secure the sugary juice; when dried they are devoured by various other moths and beetles. Seeds and grains of all sorts are attacked by the young of beetles and of moths, even when dried and stored, and also when ground up into meal.

The stores of honey and pollen gathered by the bees form important food reserves of which full use is made by other insects at the bees' expense. The social bees, like honey bees, mostly feed and tend their young and store the honey in wax cells. Their colonies, like those of the honey wasps and a few others, are continuous and their worst enemies are small moths that eat the waxen cells. Large moths, like the death's head, will also sometimes sip the honey. The bumble-bees

are victimized mainly by the cuckoo-bees. The solitary bees, the various burrowing types, the carpenters, carders, upholsterers, varnishers, etc., form lines of cells each of which is filled with food, provided with an egg, and sealed. The oil beetles and the burglar bees each have found a way of dispossessing the maker of these cells and of appropriating the food for their own young. The little stingless bees within the tropics, which have the sting so small and blunt as to be useless though their jaws are quite effectual, are social bees but with the other habits of the solitary kinds.

The organic substance of a plant transformed into the organic substance of an insect or related creature loses none of its food value; indeed in its new form it is even more desirable as food. Vast hordes of insects and their relatives of every major group subsist entirely or partially on other insects, which latter have been nourished by the plants.

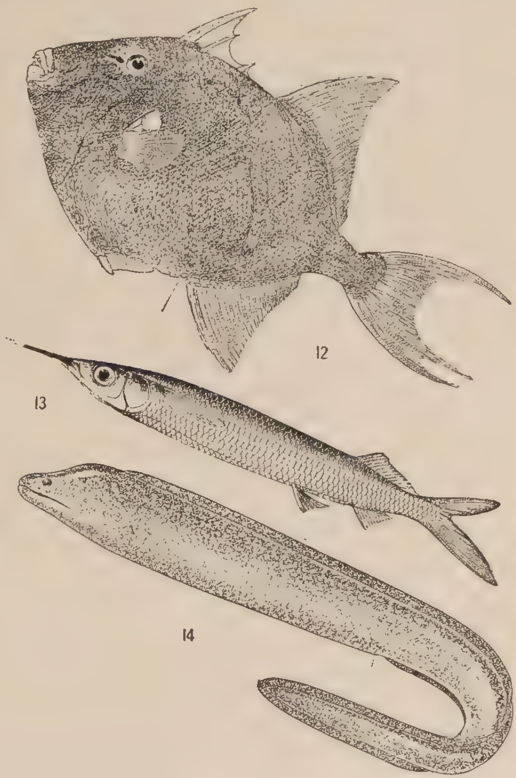
All spiders (aside from certain mites), scorpions and centipedes are throughout their lives carnivorous, catching and devouring insects of various sorts, and sometimes other creatures; for instance, giant spiders will kill and eat small birds, and giant centipedes catch lizards and are very fond of mice.

Most of the gall wasps and many gall midges, some sawflies, a few agromyzid and trypetid flies and fungus gnats, some mites and plant-lice, and some of the small moths by stinging or otherwise injuring a twig or leaf cause a pathological swelling called a gall which provides food for the grub inside. This grub may be accompanied by "guests" of other types, as well as serve as food for parasites.

Great numbers of insects subsist upon decaying vegetable matter, especially when very moist, including many sorts of flies and beetles, spring-tails and crickets, and most millepeds. It is rather curious that nearly all blood-sucking flies except the horse-flies, some mosquitoes, and the tsetse, and all the fleas, when maggots, live on or in the ground, or sometimes in water, peacefully feeding on decaying vegetation.

Thus every part of a green plant is eaten by a large variety

of insects some of which, especially among the grasshoppers and their allies, will eat nearly all parts, fresh or dried, and animal substances as well. The dead remains of a green plant, moist or dry or submerged in water also furnish food for hosts of other insects. The parasites that grow upon these plants, the mistletoes and beech-drops and all the other kinds, are also food for insects. The fungi that attack all plants and those that feed on their decayed remains furnish subsistance for swarms of different insects, especially the fungus gnats, many beetles and some termites, while other insects live on moulds and yeasts.

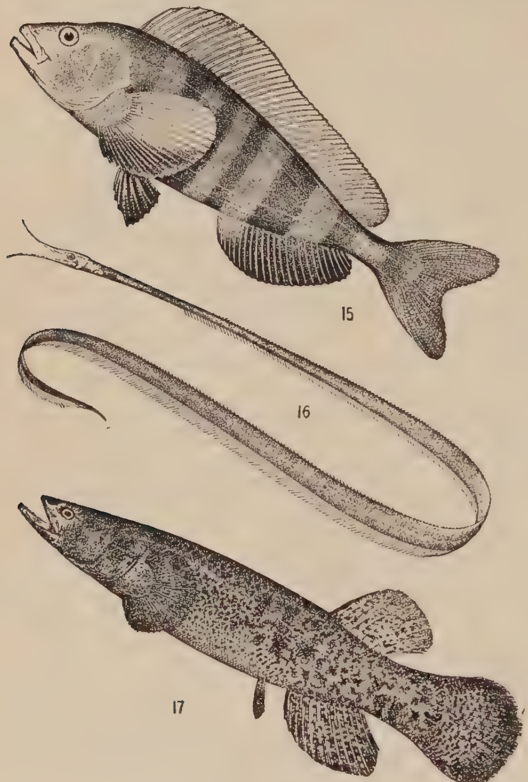


FIGS. 12–14. A Trigger-fish, a Ballyhoo, and a Moray.

For explanations of the figures see p. xi.

Of insects proper the dragon-flies and allied types, the robber or asilid flies, all the water bugs, the assassin or reduviid bugs, the mantises, hornets, and tiger, carabid, and giant water beetles are at all times predaceous, and like the spiders, scorpions and centipedes, devour mainly insects. But the larger water bugs and beetles and the larvae

of the larger dragon flies, especially when other food is scarce, are often very destructive to young fish, and giant water bugs eat small frogs and tadpoles. Generally these predaceous insects show slight discrimination in their choice of food, catching almost anything that comes their way; but most robber flies when fully grown are curious in having very special preferences. Those stout ones that look like bumble-bees eat only bees and wasps, while others catch only butterflies or moths.



FIGS. 15–17. The Atka Mackerel, a Snipe-eel, and the Tundra Fish.

For explanations of the figures see p. xi.

Slow disembowelment of the most revolting kind is practiced by the wasps. Most of these, making burrows in the ground, or boring into wood, constructing cells of mud, or utilizing chinks or burrows which they find, cram them some with spiders, some with large or small flies, or even bees, some with caterpillars, crickets, or other insects, which have been paralyzed, but not killed, by stinging. An egg is placed in each

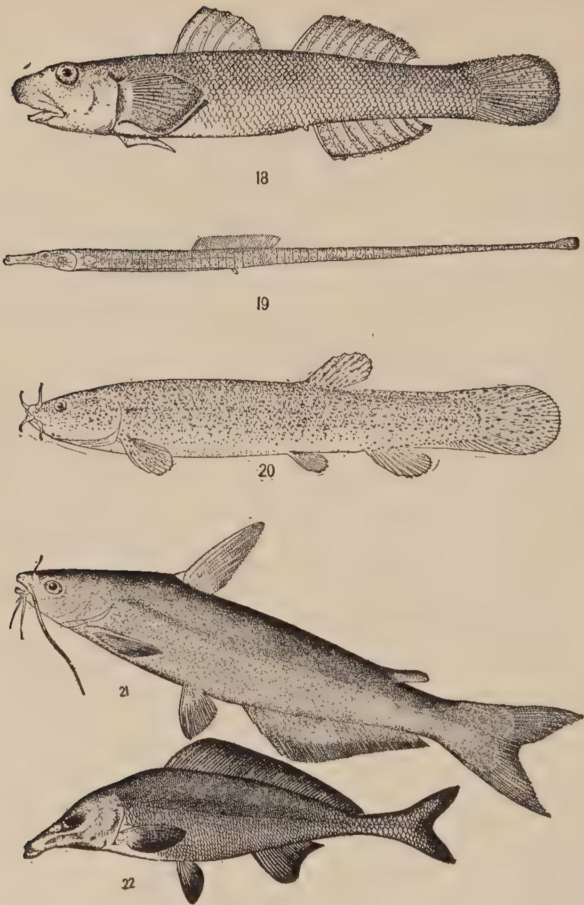
burrow or cell and the larva lives a happy and secluded life slowly devouring the store of living but helpless creatures. The great majority of these wasps select a special and restricted type of food; some take only spiders, like the blue mud wasp of our barns and attics and the "tarantula hawk" of the southwest, others only certain kinds of flies, bees, grasshoppers, crickets, cockroaches, certain types of caterpillars, etc., as the case may be. The spiders know these murderers well, and some of the web-spinning kinds will drop instantly to the ground if they see or hear one. A large and powerful kind feeds upon harvest-flies or cicadas, and not infrequently one sees a cicada in full flight shrieking piteously with one of these great wasps close behind it.

The delicate lace-winged flies, the commonest of which are green with golden eyes and smell abominably, are savage little brutes when young, feeding on other weaker and less active insects, mostly aphids. They look something like the larvae of the lady-bugs, which have the same habits, but have much longer and more slender jaws. The female lace-winged fly lays her eggs in groups, each small white egg raised on a long and slender stalk so that when they hatch the young cannot eat each other.

The ant-lions, related to the lace-winged flies, have somewhat similar though larger and much stouter, young, which mostly construct funnel-shaped traps in loose earth or sand into which small insects fall; some of them do not make traps but stroll about after the manner of young carabid beetles.

The maggots of the syrphid flies, those little flies which hover in the air and dart from place to place, are mostly aphid feeders, and you often see them in the aphid colonies. Though soft and blind and legless they seem to prosper well in spite of competition by stronger and much more active creatures.

Several of the small lycaenid butterflies as caterpillars live on scale insects or on ants, and various small moths live on the excretions of scale insects, lantern bugs, etc. Near Boston I once gathered quantities of these predaceous caterpillars



FIGS. 18–22. A Tritri, a Pipe-fish, a Loach, the Mississippi Cat, and an African fish.

For explanations of the figures see p. xi.

which were feeding on the woolly aphids of the alder and the carrion flower. Most of these were butterflies, but one was the young of a small pyralid moth.

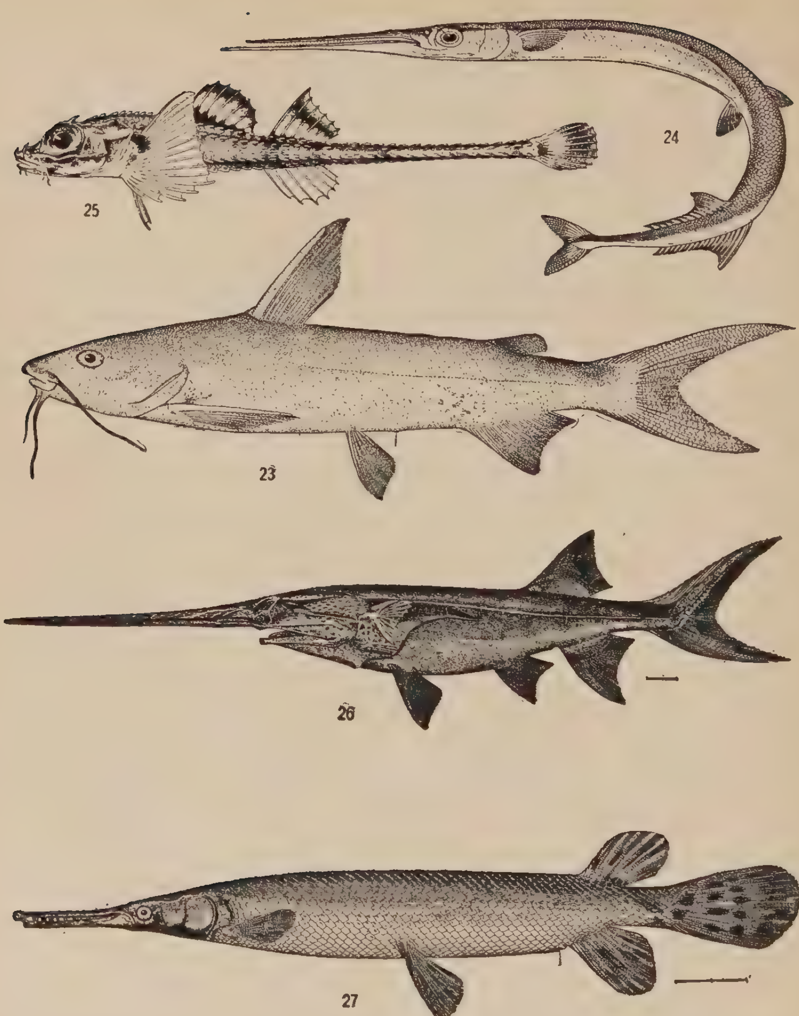
Many of the larger crickets, especially the mole-crickets, are more or less predaceous, and some enormous grasshoppers feed habitually on spiders, beetles and other insects, and even larger things like mice and lizards when they can get them. These giant grasshoppers are quite surprising things. The first I ever saw, in Venezuela, I shot, believing it as it sprang up to be a quail. The lazy walking-sticks are all plant feeders normally, but large ones sometimes will catch flies with their front legs, like mantises.

The fire-flies are all predaceous, and many specialize on snails, the larvae of some of these living in water on aquatic snails and being the only phosphorescent creatures in fresh water. Some carabids also are snail eaters; and one very curious beetle, the European snail beetle, is peculiar in having the female wingless and larva-like, resembling the glow-worms, some of which are the females of certain fire-flies.

Predaceous insects are mostly not particular in their food, and often feed on other insect eaters. Many are cannibals, normally, or when pressed for food. Crickets and many grasshoppers and the caterpillars of some of the lycaenid butterflies especially are potential cannibals.

The predaceous habit passes naturally into parasitism, a condition in which the younger stages of the insects live within the bodies of their victims eating out their substance in such a way as to avoid killing the host until they themselves are fully grown. While we may marvel at the way the solitary bees build cells, sometimes elaborately lined with leaves or felt or varnish, which they fill with food and furnish with an egg, then tightly seal, our astonishment is greater when we see how cleverly some insects have solved the problem of entering these cells and using the bee's stores, or the body of the growing bee, as food for their own young.

For instance the oil-beetles, blister-beetles, etc., mostly



FIGS. 23–27. A Sea Cat-fish, a Sea-gar, an Agonid, the Spoon-billed Cat, and a Gar-pike.

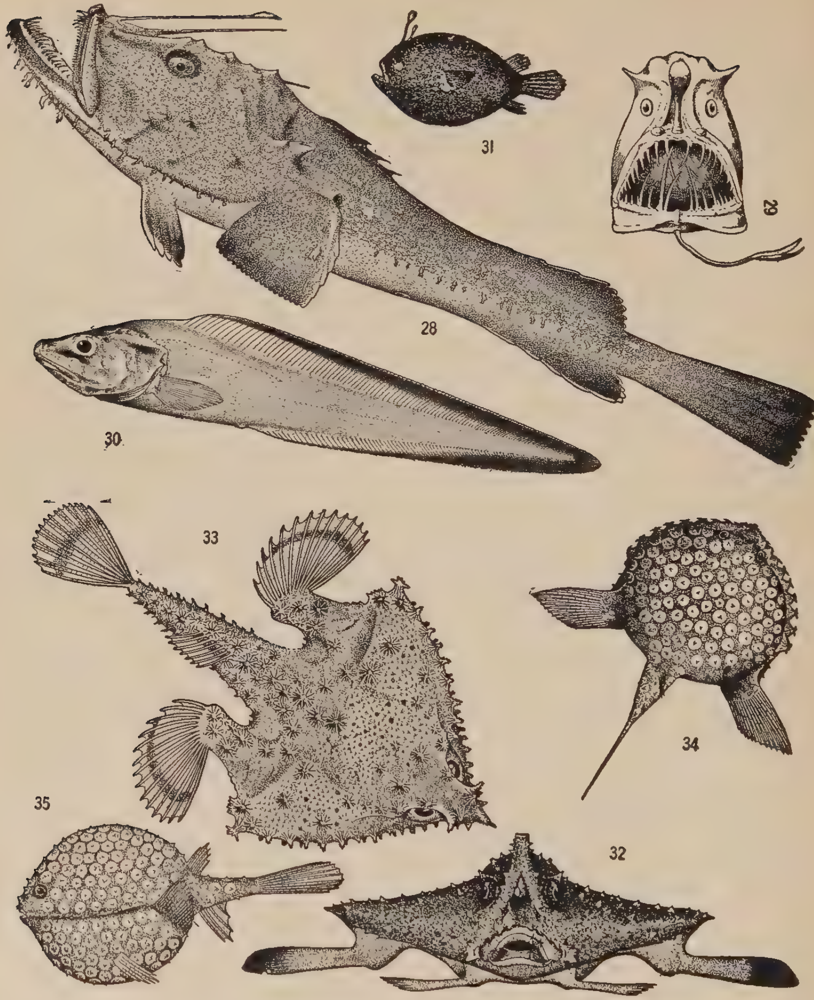
For explanations of the figures see p. xii.

hatch from the egg as active long legged larvae which, lurking in flowers, attach themselves to the hairs of solitary bees. When the cell is finished and the egg is laid on the store of honey the larva drops off and consumes the egg. It then casts its skin and a grub-like creature appears which devours the honey, changing its form and becoming more grub-like after each succeeding moult. After a false, followed by a true, pupal stage the adult beetle emerges. Carpenter bees and many other solitary bees are the victims of these beetles; some live in wasps' nests eating the grubs, and one feeds on the eggs of the rocky mountain locust. The hive-beetles are parasites of a somewhat different type, and there are still other beetles parasitic on the bees and wasps. But although very many beetles are during their whole lives predaceous, very few are parasitic.

The habits of the cuckoo-bees have already been described; then there are the burglar-bees that lay their eggs in cells constructed by the solitary bees. The curious *Stylops* and its allies are parasites that live mostly in bees and wasps. Strange minute wingless flies called bee-lice infest the honey-bees, while mites are very common. Some bees are so obliging as to have a special cavity in which their mites exist.

There are no parasites among the butterflies, and I know of only one among the moths. The larva of this species lives within the caterpillar of a large wood-boring species in Australia feeding on the fatty tissues.

It is in the wasp tribe that we find the most curious and interesting of the insect parasites. Though some are vegetarians, most of the small wasps called chalcid flies are parasites in insect eggs, in the bodies of moth caterpillars, or in the grubs of gall wasps, mason bees, etc.; many are parasites on other parasites of these. All of the pelecinid and proctotrypid wasps are parasites in other insects or in insect eggs; some of the latter will swim down under water with their wings to lay their eggs in the eggs of water insects. Some of the gall wasps are parasitic in the young of flies or saw-flies, or of other parasitic wasps; others breed in galls made by other



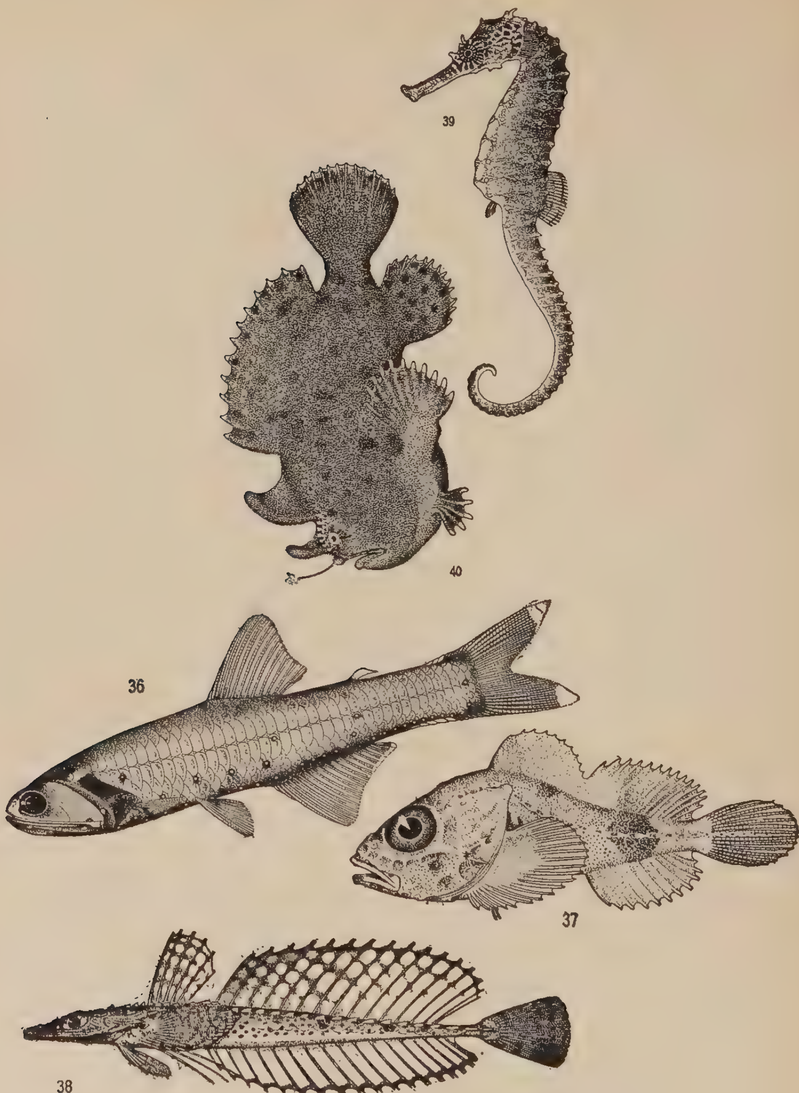
FIGS. 28–35. The common Fishing-frog, and other fishes.

For explanations of the figures see p. xii.

insects. All the ichneumon wasps are parasitic, chiefly in caterpillars, but some in wood-boring grubs, in saw-flies, bees and spiders, in other parasites, in cockroach eggs, etc. It is said ichneumons never hum so that they are able to sneak up upon their prey unnoticed. Some curious wasps, with the females mostly wingless and looking like large ants, live as larvae in the nests of bumble-bees, parasol ants, etc., devouring their young, or in various large beetles, or in other insects.

Of all the insect parasites the flies are the most nearly universal in their tastes. The great majority of tachinid flies when young live in the caterpillars of moths and butterflies. I raised some scores of these this summer, quite without intention on my part. Others live in bees and wasps, in grasshoppers and bugs, and even in other flies and earth-worms. The bee-flies proper, or bombyliid flies, are mostly parasites on solitary bees and bumble-bees, or in the latter case possibly nest scavengers. But some live in other hosts, and and among our native kinds a few of the commonest live in the young of tiger beetles.

Toads, frogs, turtles, young birds, and many mammals, especially the grass feeders, are subject to the attacks of numerous flies the larvae of which live in open sores or just beneath the skin. Other fly maggots live in the nostrils and air passages in the head, or in the alimentary tract. Representatives of all these sorts are also found in man and often cause great pain and even death. Other fly maggots live in greasy wool; and a whole group of strange flies which are curious in laying fully developed young or even pupae instead of eggs are blood suckers on birds and bats and some other mammals, like large and active lice. Some of these have wings, some have abortive wings, and some are wingless or shed their wings. The most curious one of all, called *Ascodipteron,* which lives on bats, after shedding its wings bores under the skin of its host and transforms into a soft spherical lump with not the slightest resemblance to any insect. A minute wingless fly occurs on bees.



FIGS. 36–40. A Sea-horse, and other fishes.

For explanations of the figures see p. xii.

Living more or less exclusively on the blood of vertebrates are the bed-bugs, lice, ticks, and some mites. Others sucking it whenever they get a chance are hosts of other insects, various large and vicious bugs, mosquitoes, horse-flies, stable-flies, tsetse flies, a few midges, black flies, deer flies, sand flies, fleas, jiggers, and red-bugs and other mites, many of which are terrible pests in certain places.

The true jigger, which is a kind of flea, is an interesting creature — when it is observed in someone other than yourself. The female burrows into the skin and the hinder part of her body then swells into a large ball full of eggs. If this be not removed a serious sore will follow. Yet the young jiggers, like all young fleas, live on decaying particles which they find in dust and dirt and are not parasitic.

Dead animals provide food for quantities of flies and many beetles, by which in the warmer months they are soon consumed. The blue-bottle and other flesh and blow flies are common examples. The bee-fly, common on the golden-rod in the late summer, lives often in dead animals if very moist, and habitually on decaying substances of any kind, especially in water, being enabled to breathe by extending the hinder part of its body to the surface in the form of a long tube. The adult bee-flies were mistaken for bees by the ancient Greeks, who observed them emerging in swarms from dead cattle; and this gave rise to the belief that bees were spontaneously generated from dead animals. Another type of bee-fly lives as a scavenger in the nests of bees and wasps. The Esquimaux hold the blue-bottle sacred, since the bodies of their friends and relatives go to make up its substance, and each blue-bottle is supposed therefore to contain a corresponding portion of their souls. Certain carrion flies are sometimes parasitic. If lizards are fed on the larvae of these they will proceed to feed on their internal organs and soon kill them. Or if a lizard eats one of these flies full of eggs these eggs will sometimes hatch and the lizard will be eaten out from within. Men have sometimes been killed by carrion fly larvae which bored

into them as they slept, and, much more frequently, by larvae hatched from eggs laid in the nose or on sores and ulcers. A few flesh-flies live in excrement or in rotting plants, and some in other insects and in snails.

Since, if exposed, a dead bird or rat would soon be consumed by flies, some of the large carrion beetles go to great pains to bury the carcass in the ground out of reach of the flies, thus insuring a supply of food for their own young.

Fig. 41. A Macrourid.

For explanation of the figure see p. xii.

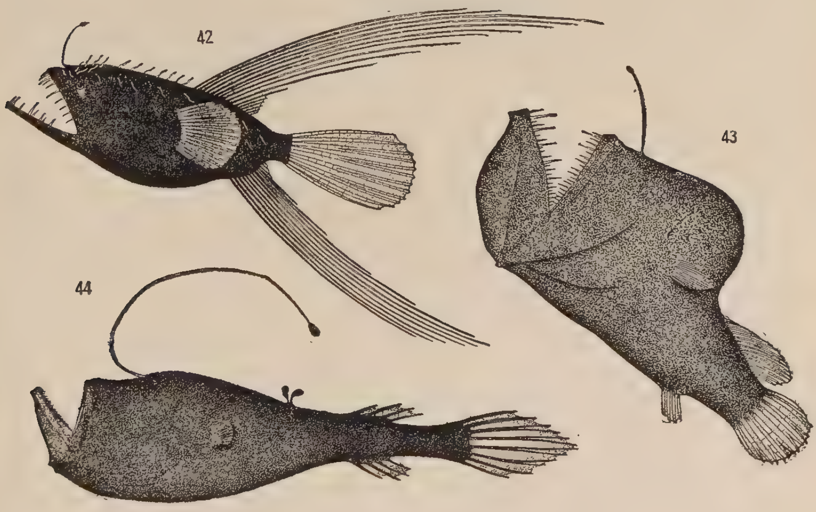
The excrement of animals forms the food of many sorts of flies and beetles, and some moths; and some of the beetles, like the scarabs, bury balls of it in the same way that sexton beetles bury carcasses. Its odor, like that of carrion, is highly attractive to many butterflies. Many flowers have one or other of these odors, and thus attract the corresponding insects.

From this brief sketch, which might be indefinitely lengthened and is perhaps too short, it is clear that insects feed not only upon vegetable material in all forms, but upon each other, upon all other kinds of animal matter both living and dead, and upon all kinds of waste material. In other words, whereever in nature there exists a constant supply, continuous or intermittent, of any substance whatsoever available as insect food, some insect type makes use of it.

Many insects, and even large groups of insects, are extraordinarily restricted in their diet, for instance the cockroach

wasps, the caterpillar wasps, nearly all bees, lice, bed-bugs, and many moths and butterflies. Other insects have a wider range; the gypsy moth feeds on a very large variety of plants, while many of the crickets, grasshoppers and cockroaches will consume almost anything of plant or animal origin. It is interesting that no one type of insect is omnivorous; the flies are the most nearly so, but very few of them consume tough or dry substances.

All of the insects, no matter what their habits, are food for carnivorous types and parasites, and over all of them hangs the



FIGS. 42–44. Three curious deep sea fishes.

For explanations of the figures see p. xii.

constant menace of disease, our common name for the attacks of those lowly organisms, mostly bacteria and fungi, which consume the living flesh. As an illustration of the intensity of the competition I may mention that about forty different kinds of parasites infest the grubs of the pine saw-fly alone.

No accurate idea of insect life is possible without a reali-

zation of the abundance of these creatures and their potentality for rapid increase. In Cyprus in 1881 egg cases of grasshoppers to the number of 1,600,000,000 and weighing 1,300 tons were destroyed with apparently little effect upon the species. A swarm of these insects that passed over the Red Sea in 1889 was estimated to cover 2,000 square miles and to weigh 42,850,000,000 tons; another swarm of similar or greater size was seen on the day following. In 1868 cockchafers were so abundant in Saxony that a reward was offered for them, and

FIG. 45. A deep sea fish.

For explanation of the figure see p. xii.

1,500 tons, representing about 1,500,000,000 were destroyed.

The most recent estimate of the total number of kinds of true insects already known is 640,920, and this number is being increased at the rate of about 6,000 every year. Large as it is it is believed to represent only about one-tenth of the real total. Of the more important groups the moths and butterflies number 205,000, the butterflies alone 50,000; the beetles number 202,400 (including 500 strepsipterans); the bees, wasps, etc., number 91,000, the true flies 45,000, the dragon-flies and more or less similar types 25,000, and the grasshoppers, crickets and their allies 20,500. Besides the true insects there are 25,000 spiders, mites, etc.

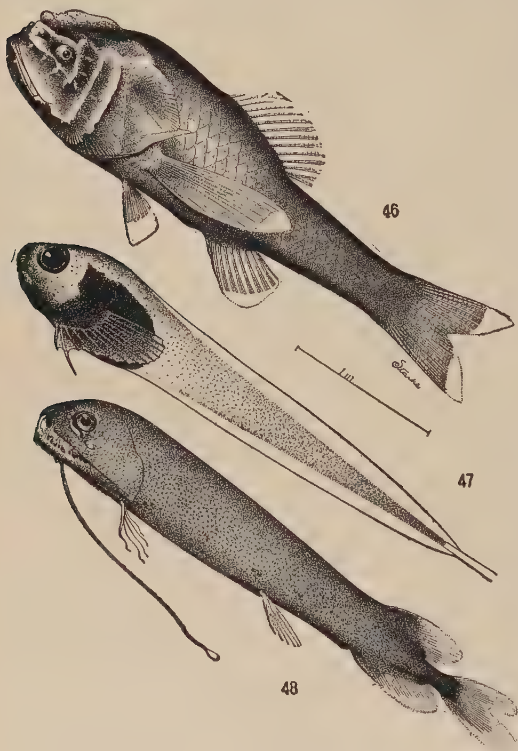
MORE ABOUT INSECTS

In the preceding pages we have sketched the broad relationships of insects to the plants and to each other, and to the different types of animal life. Now let us delve still further into insect habits and, by the selection of a few examples, emphasize the point that wherever there exists a reservoir of food of any sort, permanent or temporary, some insect type is sure to find it and make use of it; and further that to insure perpetuation of their kind the insects have made use of all conceivable expedients.

As an exclusive diet red pepper would seem to most of us to be quite unattractive; but there is one beetle which will live happily all its life in red pepper with never a thought that it is doing anything out of the ordinary. This, the saw-toothed grain beetle, is perhaps the commonest insect that habitually lives in groceries and, except for the small cockroach known as the "water-bug," the commonest in our pantries. Wherever anything edible is stored this insect will be found. It is chiefly vegetarian, but almost omnivorous, and is especially fond of cereals and breadstuffs, preserved fruits, nuts and seeds of various kinds; it also consumes yeast cakes, mace, snuff, and all sorts of medicinal roots, barks, herbs, and powders. The adults will feed upon sugar and have been reported in starch, tobacco, and dried meats, though it is doubtful if the insect breeds in such substances.

Another small beetle with almost as great a dietary range is that one that bores those neat little holes in cigars, and lives also in all other forms of dried tobacco. We sometimes find old books perforated with holes made by the grub of a small beetle, and in more southern latitudes books may be almost completely demolished by the energetic activities of the white ants or termites.

In old houses at night or when it is very still a faint ticking sound is often heard which seems to come from the beams or from the furniture. It does come from the woodwork, and it indicates the presence therein or thereon of a little beetle called the "death-watch." In dry wood their little grubs live very long before becoming large enough to transform to the adult. Last year a number of the beetles emerged from a chair I bought seventeen years ago. The grubs had been in the wood when the chair was made. Other kinds of wood boring grubs have been known to live for more than thirty years before transforming into beetles. Another little insect, a psocid, also called the "death watch," lives in chinks and crevices in houses and also makes a ticking sound at night.



FIGS. 46–48. Three deep sea fishes.

For explantions of the figures see p. xii.

The furs, feathers, and woollen clothes in our closets and the carpets and rugs on our floors furnish abundant food for various moths and small beetles, most of the latter being

known in their young stages as buffalo bugs. Dried meats, dried fruits and meal in our pantries are often found to harbour the young of moths and beetles, while in the tropics the numerous large cockroaches will frequently reduce our window curtains to shreads, destroy the bindings of our books, eat labels from bottles, or even make a meal off of our toe-nails as we sleep. The little cheese-skipper, which in these days we do not often see, is the grub of a small black fly.

About the fruit on our tables, and especially about fruit

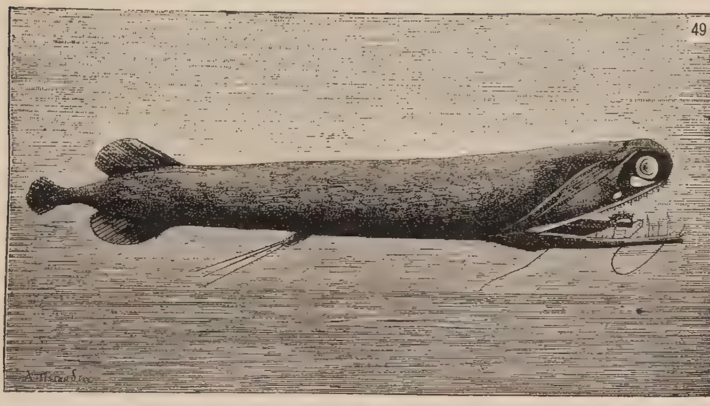
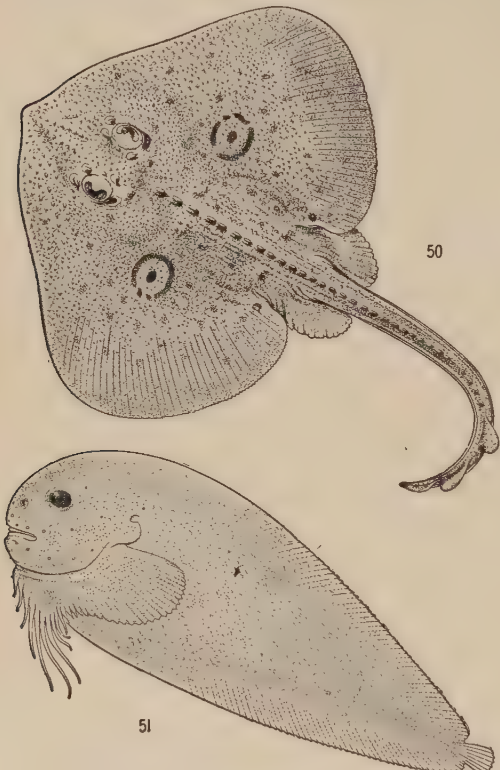


FIG. 49. A deep sea fish.
For explanation of the figure see p. xii.

exposed for sale in the markets, we often see delicate pale little flies of slow and feeble flight, quite different from the large, dark and vigorous house flies. Grapes are particularly attractive to this fly, most so when bruised. Alcohol is the magnet that attracts these flies to fruit, for they are able to live only where alcohol is present. Though swallowing alcohol, in large doses, too, with every mouthful they take in, their little grubs do not subsist upon it; what they live upon is the yeast plant which, growing luxuriantly in the decaying fruit, is continually transforming the sugar into alcohol.

Flies form the food of many spiders, and conversely spiders

form the food of many flies, especially the small headed hunch-backed spider flies. As grubs these live within the spiders or within their egg cocoons eating the eggs. These flies are rather rare; but one of the small wood wasps chiefly uses them to provide food for her young.



FIGS. 50, 51. A Skate, and a Liparid.

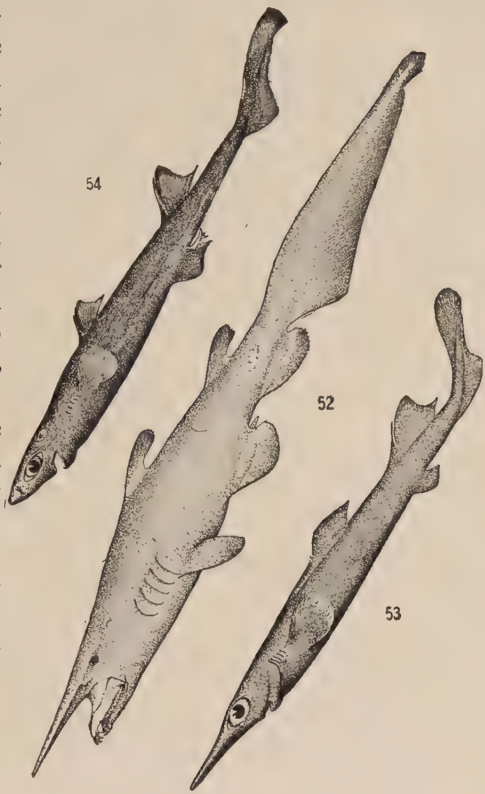
For explanations of the figures see p. xiii.

One does not ordinarily regard the butterflies as ferocious creatures, though in the American tropics the pugnacious squeaking butterflies when flying about you and attempting to frighten you away may cause you mild surprise. In our own woods, too, in the early spring the common mourning-cloak which also chirps, though faintly, will sometimes fly directly at you, and not infrequently you see it darting at the smaller birds.

Few insects are more extraordinary in their habits than the lycaenid butterflies, the group to which belong our little hair-streaks, blues and coppers. Of most of these the caterpillars, which are small and slug like, have on the back a honey gland opening on the eleventh segment. On the segment just behind

are two small openings through which are thrust two little white pillars crowned with tentacles looking like two little white sea-anemones. Ants are extremely fond of the honey from this gland and always swarm about these caterpillars. When an ant approaches the little white pillars are withdrawn and a drop of honey is exuded from the gland which the ant at once licks up. After more honey has been formed, up the pillars go again, apparently as signals to the ants.

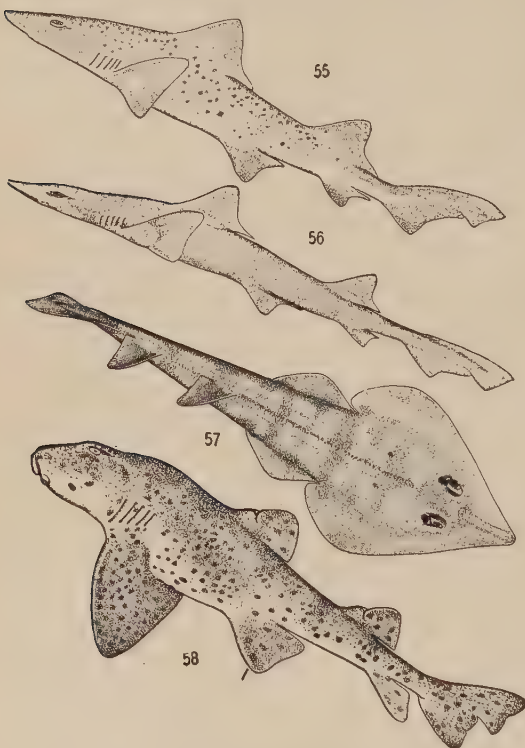
Many kinds of these caterpillars are most assiduously cared for by the ants in order that they may secure a constant supply of honey from their honey glands. Some tree ants, using their grubs as we do thread and needle, spin protecting webs about them; other ants cover them with shelters of various kinds from which they drive them out at night to feed. Some sorts of these caterpillars when fully grown are always taken by the ants into their nests where in perfect safety they undergo their transformation into butterflies.



FIGS. 52–54. Three curious Sharks.
For explanations of the figures see p. xiii.

A few ungrateful species impose upon the ants, allowing the ants to tend them and protect them from their enemies in

return for which they eat their young or consume their food supply. For instance the large blue of Europe at first feeds upon the blossoms of the thyme, giving up honey to the ants as usual; but when still quite small it leaves the plants and crawls down into ant nests thenceforth feeding on the full grown ant grubs. If you disturb an ant nest containing these ferocious little caterpillars the ants make haste to carry them to safety, leaving their own young till later. A strange thing about these caterpillars is that when they feed on thyme they are most enthusiastic cannibals; consequently you never find but one on any flower. When they leave the thyme they stop this habit, so that several may live peaceably together in one ant nest. There is another blue in Europe which lives at first on gentians,.later in ant nests sucking the blood of grubs. The very young of this are sociable in habit and do not eat each other. A species found in Africa, which has no honey gland, induces ants to feed it and lives an



FIGS. 55–58. Four sharks.

For explanations of the figures see p. xiii.

easy life by appropriating for itself food collected and intended for the ants' young. Related to this is a very large one in the Indian region which lives in the nests of the green tree-driver ant eating their young.

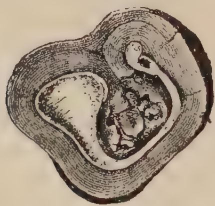
The caterpillars of several other kinds, among them one of ours, feed wholly on aphids or scale insects, and a few additional eat these in their later stages. Some eat other insects. Other lycaenid caterpillars feed on bark and lichens, or bore into fruits or seeds.

The caterpillars of most of these pretty little butterflies are cannibals, and especially prefer to eat their friends just as they are changing to the pupa stage.

Moths are much more varied in their habits than are the butterflies, just as they are also far more numerous. A number of them as caterpillars feed in ant nests on young ants, or on scale or other insects, or on the excretions of fulgorids. A few are parasities in other caterpillars like the grubs of tachinid flies. Many eat dry animal matter of all kinds, including horn. One lives in the water in the leaves of our common pitcher-plant eating the insects which the plant has caught. In the American tropics one eats only a certain lichen which is never found except upon the rough and brittle hair of living sloths. Most moths, of course, like nearly all the butterflies, are vegetarians, mostly leaf feeders, sometimes borers.

Is there any better food than lobster or crab meat? If there is, then one whole group of insects shows poor judgment, for they eat nothing else, except that for them minute crustaceans replace the crabs and lobsters. These insects, related to the common water striders of our ponds and streams, live upon the surface of the ocean, often far from land, picking these dainty morsels from the water. These are the only truly marine insects, though a spider, some centipedes, and a few spring-tails and carabid beetles live under stones between tide marks, and the spring-tails on the surface of tide pools, and the various beach-flies live in the rotting sea-weed cast up by the waves.

The common pitcher-plant lives partly on the insects so unfortunate as to fall into the water in its pitchers which are there digested and their juices then absorbed by the inner surface of the leaf. These masses of dead insects in process of digestion have been discovered by enterprising living insects which find in them a store of excellent food for the support of their own young. In the late summer cut a few leaves from a pitcher-plant, slit them open, and pour the contents out on a white plate. Among the packed remains of insects you will see mosquito "wigglers," a number of slender and translucent grubs, commonly several to a pitcher, and possibly you will also find a large fat whitish maggot, and a small caterpillar encased in the dead remains of insects.



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FIGS. 59, 60. A section of a manganese nodule, and the tooth of a giant extinct shark.

For explanations of the figures see p. xiii.

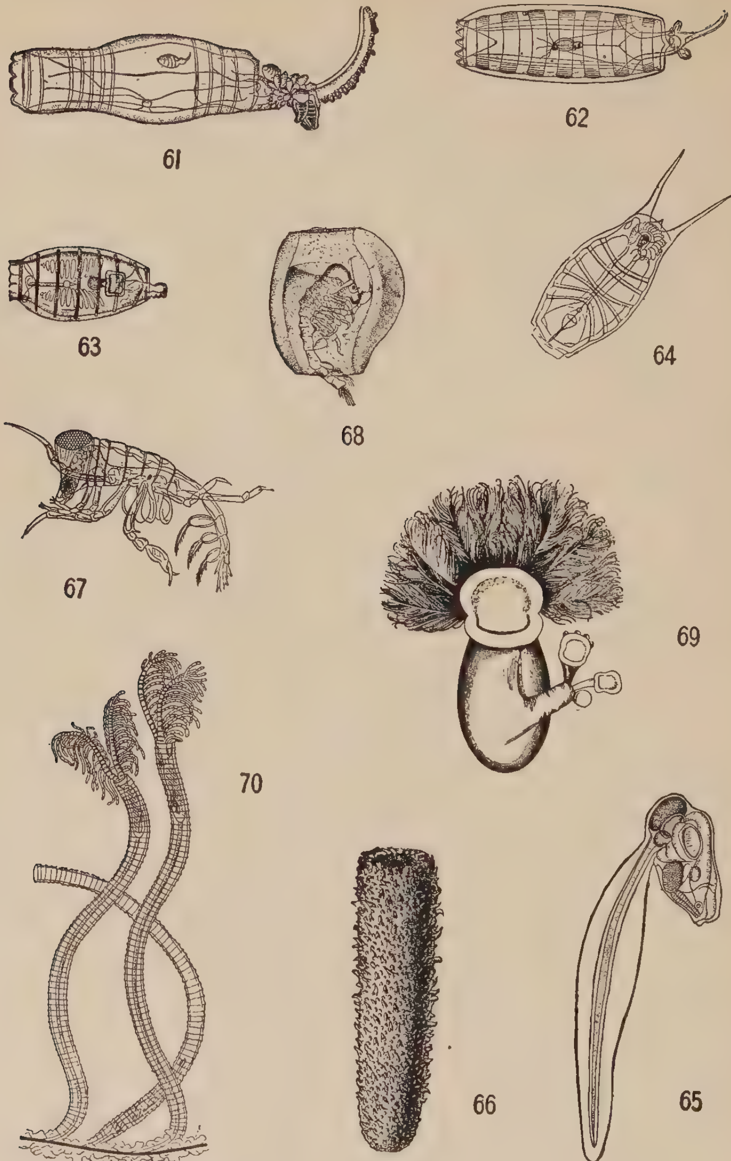
The "wigglers" are the young of a very pretty mosquito which breeds nowhere else. You can raise these safely in your house as they do not bite. In the winter you can find these "wigglers" frozen solid in the cones of ice within the pitchers, and if you melt these cones they come once more to life. The slender and translucent grubs are the young of a kind of gnat found nowhere else, though

related forms live everywhere in water. The large white maggots are the young of a large blow-fly which never "blows"; there are half a dozen kinds of these occurring only in the leaves of pitcher-plants. There are also various other less conspicuous things within these pitchers.

Another plant we have which feeds on insects, the elegant little *Drosera* or sun-dew so common in our northern bogs and woods and often associated with the pitcher-plants. The sun-dew and its allies exhale a fungus-like odor which appears to be especially attractive, and therefore fatal, to the fungus gnats. In Australia, the headquarters of the sun-dews, there is a very large one with an enormous appetite. On this kind and nowhere else there lives a long legged bug which walks up and down the leaves sucking the juices from the insects which the plant has caught.

Agriculture is practiced by different ants in various highly specialized forms. The so-called leaf-cutting ants gather great masses of green leaves which they chew up and place in their nests. These ants are large and powerful and very business-like, and at Carriacou a party of them once in a single night cut out all the cabbages from the garden of a friend of mine with whom I lived. The cabbages were growing finely, and we had hoped the ants had overlooked them. Upon the wilted leaves within the nest there grows a fungus, and upon this only do the ants subsist. This fungus is never allowed to fruit, the fruiting heads being bitten off as soon as they appear. A female ant, starting out to form a new colony, carries some of this fungus in a depression underneath her tongue; of her first batch of eggs she crushes a few and on them plants the fungus which lives upon the eggs until enough workers have appeared to form a new garden.

Most of the food we eat has been cooked and more or less altered, though we can, if necessary, live on uncooked substances. But the white ants or termites are quite unable to live upon the food they eat. They consume cellulose, a substance they are unable to digest; their alimentary tract,



FIGS. 61–70. Various sea animals.
For explanations of the figures see p. xiii.

however, is tenated by numbers of minute creatures which attack the cellulose and break it down into other substances, and the termites digest the results of their activities. The termites, therefore, live entirely on the products of other creatures, and without the coöperation of their little friends inside them they would soon starve to death no matter how much of their favorite food they ate.

Beggars never making any attempt to work, and indeed incapable of doing anything at all, occur among the insects. Beetles of this description live in ants' nests where they are fed and cared for by the ants with as much solicitude as if they were their own young The beetles, wasps, crickets, spiders, wood-lice, larvae of flies, moths, butterflies, etc., and even larger things, like legless lizards, that live in ants' nests are a most absorbing study in themselves. Some are parasitic, others probably scavengers; but why most of them are tolerated there we do not know.

Incompetent decrepit beggars asking charity are one thing; energetic and powerful ruffians enforcing charity quite another. Certain ants come in the latter category Beyond raiding the nests of other species, killing the workers and carrying off the pupae, these ants do not work at all. The pupae they raise as slaves, and these slaves perform all the work for the colony, making the nest for and raising the young of their masters. The so-called cuckoo-bees have somewhat similar habits, living at the expense mostly of the bumble-bees the various species of which they resemble in color, though they are usually somewhat larger than their victims and lack the pollen basket on the hind legs. Cuckoo-bees are all males or females, without workers. A cuckoo-bee, entering a bumble-bees' nest, appropriates the wax and honey, often killing the queen if she interferes. Her young are then fed through the efforts of the worker bumble-bees at the expense of the colony, which produces no male or female bumble-bees, only cuckoo-bees.

Narcotic peddlers have their representatives among the

insects. There is a curious bug in Java which feeds on ants. When an ant approaches it rises up, exposing some long hairs on the under side which are wet with a secretion from some special glands. The ant greedily licks off this substance which, however, is intoxicating. When the ant has had enough to make it "groggy" the bug with its sharp beak stabs it suddenly through the neck and sucks its juices out.

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FIGS. 71, 72. A pair of African Swallow-tails.

For explanations of the figures see p. xiii.

Very many insects if shut up together without food will eat each other, like many caterpillars, grasshoppers and crickets. Others most willingly do this merely if they get the chance, like the young of lace-winged flies and of some butterflies. For still others cannibalism forms a part of their regular routine existence, and they contemplate their relatives with the same lack of sentiment that we do buns or muffins.

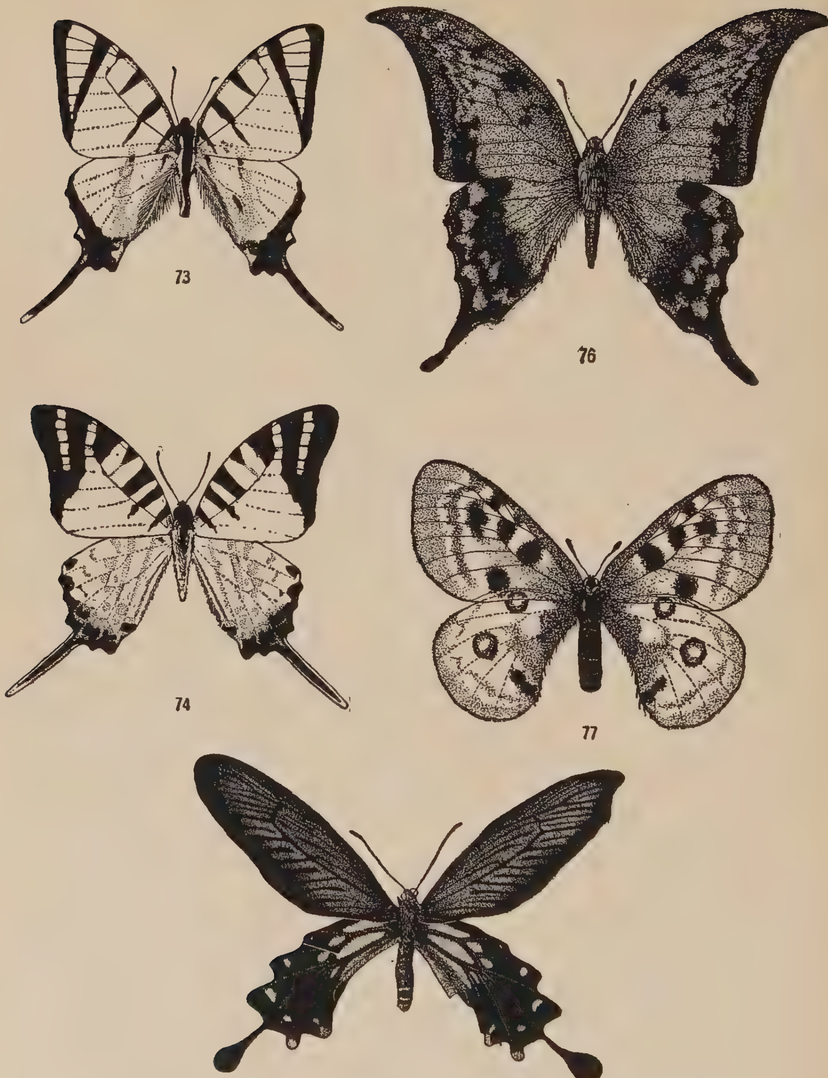
Their own brothers and sisters form the regular nourishment of many spiders in their early stages. The female spider lays a quantity of eggs within a silken ball. When these eggs hatch a sanguinary riot starts within this ball and the little spiders eat each other

until those that survive are large and strong and fierce enough to face the outside world.

Few of us I hope, no matter how sorely pressed by hunger, would eat our mothers, and yet this is the fixed habit of several insects. Perhaps the strangest of these is a little fly, one of the gall-midges, which as a grub is found beneath the bark of trees. The grubs of this gall-midge produce a number of young within their own bodies which immediately proceed to eat their mother, and when she is but a memory they bore out of her empty skin and start life on their own account. A swift retribution overtakes them, however; for young appear within them and they are devoured in the same way. This process of progressive mother eating continues all the winter, and at the beginning of spring the now very numerous grubs transform into adults.

Large, portly and ferocious wives, bloodthirsty in disposition, bring to an end the happy lives of many insect husbands, as among the mantises where the female always eats her mate; while many female spiders, much larger and much more powerful than the males, seem to take a keen delight in killing or maiming them.

For all the strange habits mentioned heretofore we can see a reason, though perhaps that reason seems peculiar. But the metal chewing habits of some other insects are not easily explained. During the Crimean war much damage was done to the lead bullets used by the French army through the activities of an insect larva or grub which bored holes through them. This circumstance first brought into general notice the fact that various insects of a number of groups eat metals and other mineral substances. About twenty years ago the activities of lead boring insects working on the lead sheathing of aerial telephone cables in California began to attract attention, and later telephone fuses, underground cables, and other structures in various places, especially within the tropics, were found to suffer from insect depredations.



FIGS. 73–77. An alpine butterfly, and four oriental swallow-tails.
For explanations of the figures see p. xiii.

Lead is the metal most commonly injured. Lead bullets and cartridges, lead, and also tin, roofing, lead rain gutters, lead stereotype plates, lead piping for both water and gas, lead lining of vats, tanks and cisterns, the sheet lead protection for bee-hives, lead crucibles, lead fuses, telephone batteries, the lead sheathing of aerial telephone cables, high tension cables, and lead covered cables in wooden cased conduits, all have suffered from insect attacks. But lead is not the only metal to suffer. The quicksilver backing of mirrors, the gilding of chandeliers, silver plate stored in closets, tin and zinc, are also sometimes damaged. Shell, horn, and even asbestos are bored by insects.

The variety of insects which will damage metals is quite considerable. It was a horn-tail that bored the French cartridges. A wasp has been found to damage lead cables in China. White ants or termites have damaged lead cable sheathing underground. The larva of the goat-moth sometimes causes trouble. But the worst culprits are beetles of no less than eleven different families or major groups.

At first it was believed that the insects fed upon the metal through which they bored, and, indeed, lead and zinc have actually been found in their stomachs. But with few exceptions the cases recorded are merely accidental, though none the less troublesome, resulting from the fact that the metal blocks the path of an emerging adult or of a boring larva, and do not constitute direct attacks. As an example, near Saarau, in Silesia, a new sulphuric acid factory was built of timber infested by horn-tails. The adults emerged through the lead floor plates causing a loss of about $25,000. But in some cases the insects, for unexplained reasons, do make a direct attack, often with serious results.

THE FOOD OF THE OTHER LAND ANIMALS

WE have seen that every part of a plant, and vegetable and animal matter in every form, is utilized as food by insects, and that all insects themselves serve as food for other insects, spiders, and related types, as well as for various parasitic plants.

Insects alone would dominate the world, consuming all the surplus that could be spared by plants, were it not that they are restricted in their sphere of action by three main considerations. Their great muscular activity necessitates a constant and a large supply of oxygen without which they would soon become inactive and eventually perish, as well as abundant food of a relatively high nutritive value, and their external skeleton and method of breathing by slow diffusion of oxygen wholly or chiefly through minute rigid tubes imposes upon them a relatively small maximum size.

There is room on the land, therefore, for other animals with a more perfect system of respiration and an internal skeleton, admitting of a much larger size and greater activity; for less active animals with a less consumption of oxygen; and for less active animals capable of existing on food with less nutritive value. The animals with a more perfect system of respiration and with an internal skeleton are the vertebrates — the mammals, birds, reptiles and amphibians; those with a less oxygen consumption are the land planarians, nematodes or threadworms, most slugs and snails, and the land nemerteans; and those capable of existing on food with a minimum of nutriment are the earth-worms and some snails.

The land leeches, land crustaceans, and onychophores would seem to be direct competitors of the insects which have met with limited success. The vertebrates, with a structure eminently fitted for terrestrial life and which allows of a very

large maximum, though at the same time permits only a relatively large minimum, size, find themselves existing in a world abounding with vegetation upon which directly or indirectly countless hordes of insects live, together with snails and slugs and earth-worms and, near the water, crabs. Other animal types are in negligible quantity and keep themselves hidden from sight.

Their large size and great muscular power enable the land vertebrates to ignore the insects as competitors for the vegetation, as well as to utilize them, the earth-worms, the snails and the crabs as food. One curious fact in regard to the vertebrates is that the less perfected types are all, or nearly all, carnivorous, plant-eating forms being found only among the more specialized.

The amphibians — frogs, toads, salamanders, etc. — like the fishes are almost exclusively carnivorous, feeding on insects, slugs and worms, while the very large toads will even devour young chickens and mice. But the tadpoles of some of them for a greater or lesser period feed on algae and plant remains in water, and the curious *Siren* is strictly vegetarian. A few are worm or snake-like and live underground, while others live in caves deep under ground and, blind themselves, like the blind fish feed on blind crustaceans None are marine.

The great majority of the lizards are carnivorous, the larger feeding on small mammals, birds, fishes and eggs, the smaller on insects, worms and other invertebrates; but a number are herbivorous, as the larger iguanas and many agamids. One iguana, the only lizard that can be called marine, though living on land in the Galapagos Islands feeds beneath the water on sea-weed. A number of lizards of different groups are limbless and snake-like, some of these living underground like worms. The crocodiles, alligators, caymans, and their allies are all carnivorous. Some American crocodiles are marine, the others living in fresh water.

All the snakes are carnivorous. The burrowing snakes, which live underground and are small and never poisonous, feed on

FIGS. 78–87. Various butterflies, and a day-flying moth.
For explanations of the figures see pp. xiii, xiv.

insects, worms, etc. The sea snakes, with much the same habits as the large tropical eels though usually more helpless on land, are fish eaters, and all are poisonous. The terrestrial snakes and the tree snakes, many of which are very venomous, feed chiefly on vertebrates, including other snakes; some eat eggs, and the smaller ones eat insects. The fresh water snakes eat frogs, fish and other aquatic animals. Rattlesnakes feed only on warm-blooded animals, the eastern diamond-back, for instance, almost exclusively on cotton-tail rabbits.

The land tortoises, a few terrapins, and some of the marine turtles are vegetable feeders, but most turtles are carnivorous, feeding on fish, frogs, insects, and other small animals. Our common snapper often bites the feet off of young ducks.

As a group, the birds are set apart from all the other vertebrates by their superior method of locomotion, combined with their superior vision. Small birds are preëminently destroyers of insects, which they catch in the air like the flycatchers, swallows and goatsuckers, pick off the leaves like the vireos and most warblers, search for on the ground, like most thrushes, water-thrushes, starlings, etc., dig out of wood, like the woodpeckers and wood-hewers, extract from flowers, like the humming-birds, find concealed in the crevices of bark, like the creepers, or even pursue under water, like the dippers.

Some show decided preferences, like robins for earth-worms, starlings for millepeds and flickers for ants, though robins and flickers eat many types of insects and even fruit, while kingbirds, like phoebes and other of the larger flycatchers, are very fond of young fish. But by no means do all small birds exist entirely on insects. There are many seed and fruit eaters among them, especially among the finches or sparrows, though these often feed their young on soft insects, and many birds normally or chiefly insectivorous will subsist on vegetable material if forced to do so.

The larger birds tend more toward segregation into vegetarian and carnivorous types, both inclining toward further specialization along particular lines. The pigeons, parrots, os-

triches, swans, geese, many ducks, and gallinaceous birds are examples of exclusively or primarily vegetarian types, while

FIGS. 88–92. A Whip-cracker, a day-flying moth, the Spurge Hawk Moth, and the Pandora Moth, with dried caterpillars.

For explanations of the figures see p. xiv.

the eagles, hawks, owls, cormorants, pelicans, gulls, terns, gannets, herons, storks, and vultures are examples of exclusively carnivorous types. But cranes are more or less omnivorous.

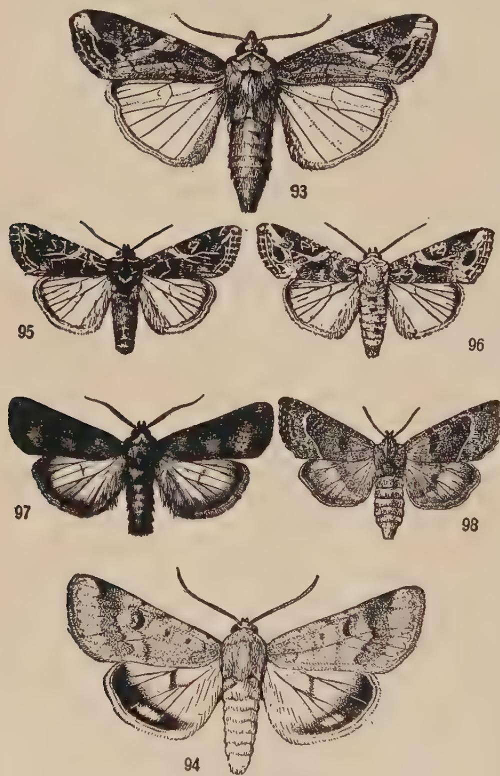
Some vegetarians have a very limited diet, the hoactzin,

for instance, eating only the leaves of *Arum;* this is especially the case, however, in the carnivorous forms because of the widely varying habits of their victims. Many birds, including certain African and Malayan owls, certain hawks, some eagles, the pelicans, cormorants, gannets, large herons, large kingfishers and most terns subsist entirely or chiefly upon fish. The secretary bird and certain kites, like our swallow-tailed kite, are reptile feeders, preferring snakes; the road-runner, a curious cuckoo, feeds extensively on lizards; the everglade kite and the limpkin live on molluscs. Certain strange crepuscular hawks eat bats, which they swallow whole, with an occasional bird, and vultures feed on carrion.

Of smaller birds with curious or specialized feeding habits may be mentioned most cuckoos and the caterpillar shrikes, which feed mainly on caterpillars; the crocodile birds, which subsist largely on the parasitic crustaceans which they pick off the gums of crocodiles; some ant-thrushes, which feed more or less extensively on ants, insects also preferred by the ant-shrikes and the ant-eating woodpeckers; and the ox-peckers, which feed largely on the sores on the backs of cattle caused by large fly maggots just beneath the skin. Some birds, like crows and ravens, will eat almost anything either of animal or vegetable nature.

Sudden increase in animal life of various kinds usually results in the convergence upon it of various birds some of which do not ordinarily subsist upon that particular creature. Ponds in which small fish, especially trout, are raised are haunted by a large assortment of birds, many normally insectivorous, which raid the young fish. Plagues of grasshoppers attract quantities of terns and small gulls, small birds of prey, gallinaceous birds, crows, and various finches. Ant armies in the tropics are followed by many birds, a few picking off the ants, but most watching for the insects, small mammals and reptiles fleeing in terror from them. The appearance of the seventeen year cicada is accompanied by a temporary change in the habits of very many of our birds which, ordinarily living in

the open, take to the woods to avail themselves of the abundance of new food. The English sparrow, for instance, and near the coast the gulls and terns for a few weeks become more or less of woodland denizens, subsisting for the time being almost entirely on these insects.

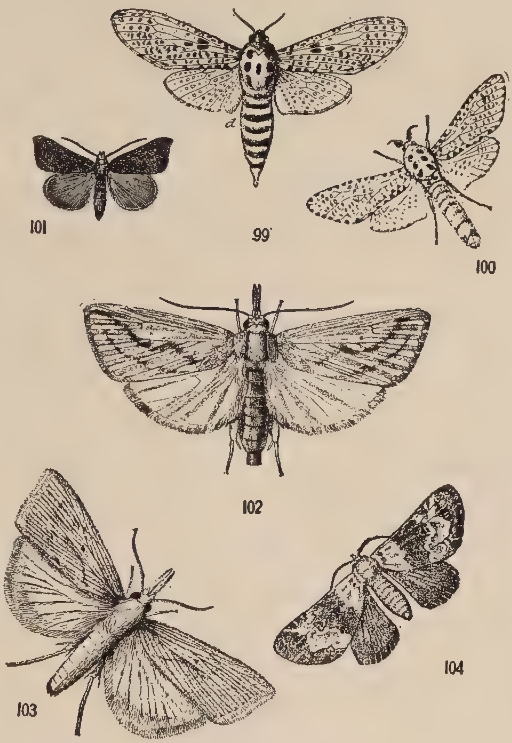


FIGS. 93–98. Six destructive moths.
For explanations of the figures see p. xiv.

Many birds are very enterprising in discovering new foods, or in adopting them from other birds, especially when introduced into new surroundings. New Zealand has no mammals except for a few bats. Just how one of the large native parrots there acquired the propensity for eating the kidney fat of sheep is not quite clear. But the slowness, clumsiness and stupidity of the larger parrots when compared with most other birds seems to be combined with a habit of trying anything that looks edible, in correlation with a flexibility of habit in other ways. Perhaps it should be mentioned that tame parrots will readily eat an extraordinary variety of substances, and are often very fond of meat. English sparrows ordinarily will not eat sunflower

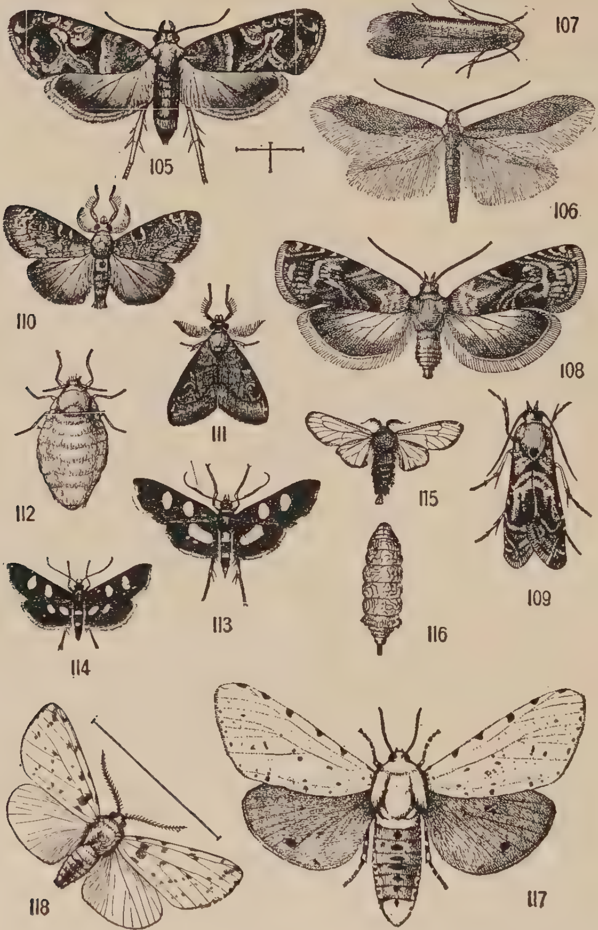
seeds; but if they see another bird, as a cardinal, eating them they will promptly follow suit.

The flight of birds gives them a very great advantage in the search for food. As birds cannot hibernate and require a very large amount of food in proportion to their weight on account of their great activity and high temperature, which is normally as much as 110.2° in some, the colder regions would be almost birdless were it not that the birds are able, when the waters freeze and the land life passes into the winter conditions, to fly southward to regions where they can still find abundant food. Tropical birds of many kinds also wander about over more or less definite tracks at different seasons.



FIGS. 99–104. Moths.
For explanations of the figures see p. xiv.

There are various types of parasitic birds which live by robbing other birds. Most, but not all, of the Old World cuckoos, though only one of the American so far as known, lay their eggs, or rather place them, in the nests of other smaller birds; the young cuckoo, shoving the other young birds out of the nest, is reared by the foster parents. The



Figs. 105–118. Moths

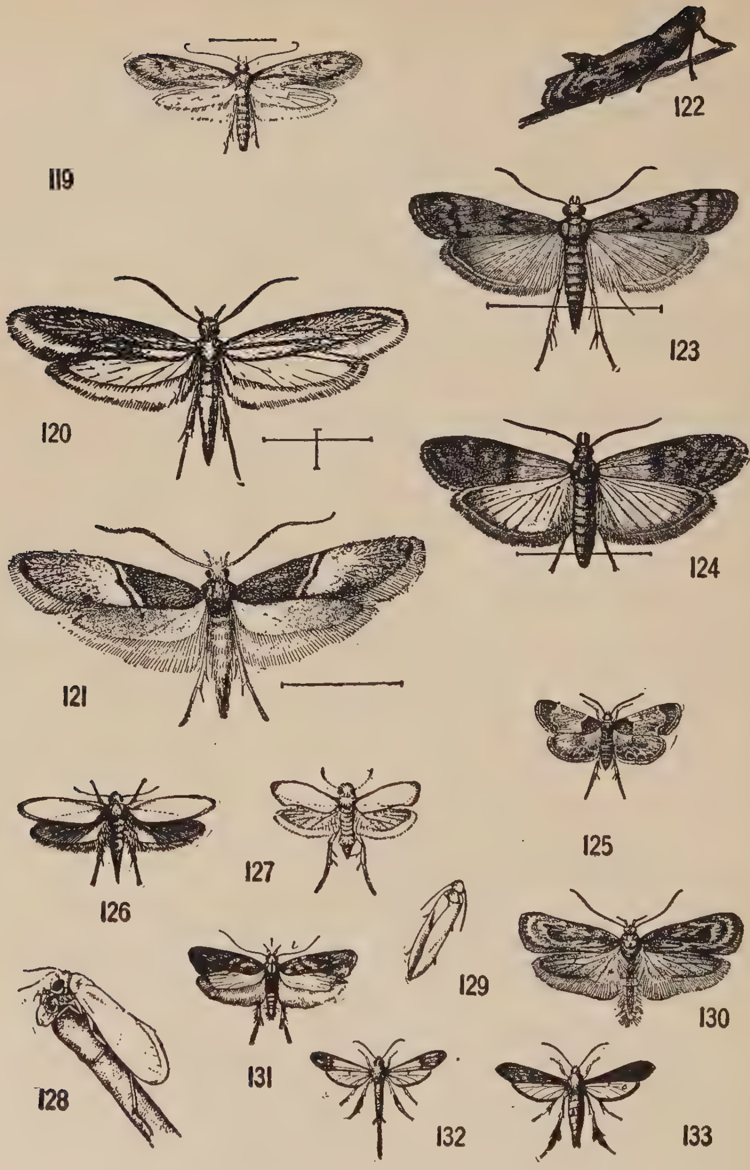
For explanations of the figures see pp. xiv, xv.

great spotted cuckoo victimizes magpies and even crows, birds which we look upon as unusually intelligent. In North and South America most, but not all, of the small blackbirds known as cowbirds because of their fondness for the company of cattle have the same habit. The adults of most cuckoos are caterpillar eaters (some eat lizards), and the cowbirds are insectivorous. The jaegers, the skuas, the frigate birds, and, to a lesser extent, the bald eagle rob other fish eating birds of their prey, while the large gulls feed very generally on the eggs and young of other sea birds and the crows and jays destroy the eggs and young of birds in our woods and orchards. Some birds, like the house wren, will destroy the eggs of other birds for no apparent reason, as they do not eat them.

As a group birds are chiefly animal feeders, devouring mainly insects and other invertebrates, especially crustaceans, but also all other vertebrates, including each other, and carrion; many are fruit and seed, some honey, and a few leaf eaters. The harder parts of plants, vegetable detritus and the fungi are left practically untouched.

In sharp contrast to the amphibians, reptiles and birds, the mammals are chiefly vegetarians, especially leaf, twig and root eaters. By far the largest group is that of the rodents, including rats, mice, squirrels, porcupines, hares, rabbits, beavers, voles, etc. These are mostly small but very numerous in individuals, terrestrial or burrowing, more rarely tree inhabiting or aquatic, and feed almost wholly on the roots, bark, stems and leaves of plants, or on seeds or nuts. Some, especially the smaller mice, are very fond of insects and will feed largely upon them if they are able to get them.

The sea-cows are all vegetarians, the marine forms eating sea-weeds and those living in rivers water plants. The elephants and the numerous hoofed animals and their allies are all terrestrial and all leaf eaters, some consuming also twigs, bark and roots, as well as lichens. A very few, like the pigs, are more or less omnivorous and will sometimes feed on other animals. These creatures are of large size, nearly all, except



FIGS. 119–133. Moths.

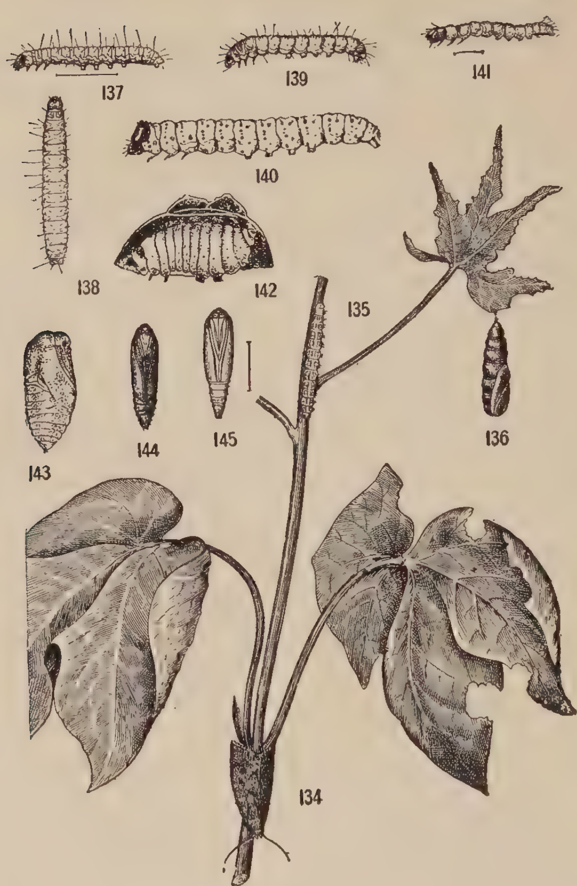
For explanations of the figures see p. xv.

for forest living types, gregarious, and taken all together represent an enormous bulk. Over much of the world the native types are now much reduced in numbers or even have become extinct; but the balance has been little changed, since they have been replaced with domestic cattle, horses, sheep and goats.

The so-called edentates, including the sloths, ant-eaters (except the Australian), armadillos, pangolins and aard-varks, are all uncanny ludicrous beasts with strange habits; they are few in species and, with some exceptions, rather rare. The sloths live in trees and never come to the ground; all feed on leaves. The ant-eaters live on the ground or in trees and feed mostly on white ants, though also eating other insects. The aard-varks, with the same habits, live in burrows. The pangolins and armadillos are burrowing or terrestrial, but one small pangolin lives in trees. The pangolins and some armadillos are mainly white ant eaters; other armadillos will eat other insects as well or even most animal substance, living or dead.

The insectivores include a large number of mammals, mostly terrestrial, a few burrowing, tree living, or even aquatic, represented by the moles, shrews, hedge-hogs and allied creatures, most of which live chiefly on insects, though the moles eat mainly earth-worms, another type lives on fish, and still another is partially herbivorous.

The carnivores, the lions, tigers, jaguars and other cats, the wolves, dogs, foxes, bears, ichneumons, otters, skunks, raccoons, seals, and various other forms, are all carnivorous, mostly feeding on other vertebrates, especially on other mammals, birds and fishes, the smaller largely on insects, and some, like the hyaenas, chiefly on carrion. A few, such as the crab-eating raccoon, have curiously specialized habits. The walrus feeds on molluscs. The reverse of the habit recently adopted by the New Zealand kea is exhibited by the Mediterranean seal which, living on fish, has a fondness for grapes and is said sometimes to commit great havoc in the vineyards of Sardinia and Sicily at the time of the vintage.



FIGS. 134–145. The cotton Leaf-worm Moth in all stages, and the caterpillars and pupae of other moths.

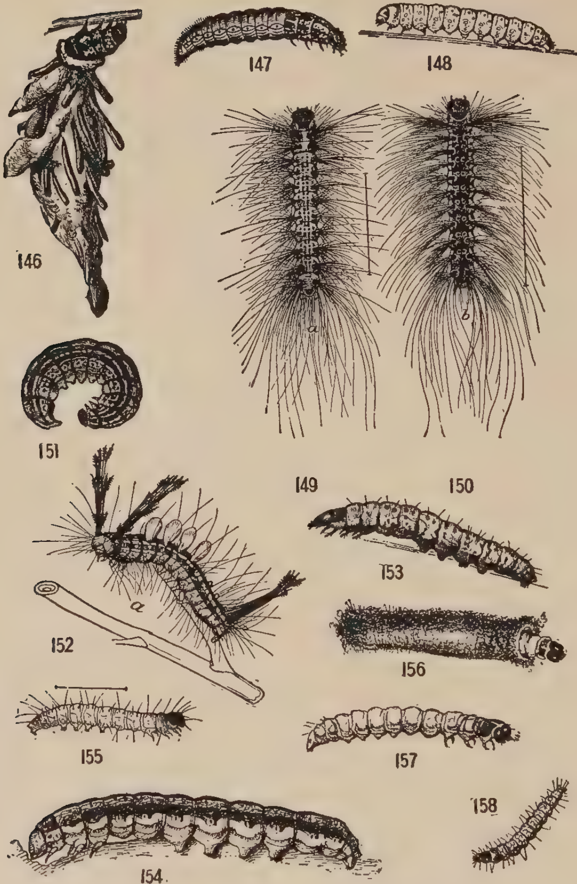
For explanations of the figures see p. xv.

The bats, all of which fly, like most birds, though guided by their hearing instead of by their sight, are nearly all carnivorous, and mostly insect eaters; a few catch birds, one is a fish eater, some are blood suckers, and several of the largest ones eat fruit, often committing serious depredations.

In Australia except for the so-called monotremes, including the spiny ant-eaters and the duck-billed mole (*Ornithorhynchus*) which lay eggs like birds, for the bats and for some rodents, all of the mammals are of a single type called the marsupial because in nearly all, the females possess pouches in which their singularly helpless young are reared. In the absence of competition from more efficient types the marsupials in Australia have to a considerable degree paralleled the chief mammalian types found in other lands, some being vegetarians, like the kangaroos, others fierce predaceous beasts like the marsupial wolves and the Tasmanian devils, some ant-eaters, some feeding on insects generally, and some more or less omnivorous. Outside of Australia the only marsupials are the carnivorous opossums of South and southern North America.

To complete the picture of life on land let us consider briefly the food of the few remaining groups.

The land molluscs, the snails and slugs, occur everywhere and form the most numerous and important animal group after the insects and the vertebrates. Nearly all of them inhabit damp places out of doors, or cellars, and are active only at night or in wet weather. They feed chiefly on decaying vegetation and on fungi, but often on green vegetation and on fruit, sometimes causing much damage in gardens. Some pass sand or mud through the alimentary canal, digesting out the organic particles, like earth-worms. A few are more or less carnivorous, earth-worms being their chief victims. One land snail possesses the power of boring into rock. In addition to the snails and slugs, a small bivalve, like a minute clam, is sometimes found among moist leaves in the woods, usually near water.



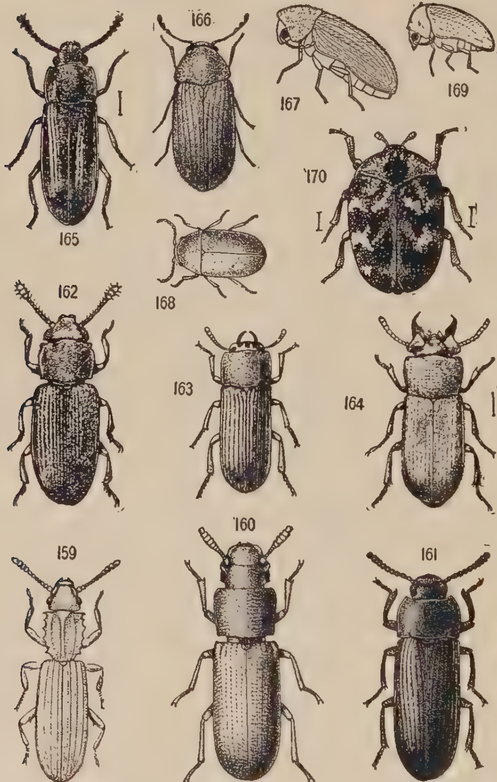
FIGS. 146–158. Caterpillars of various moths.

For explanations of the figures see p. xvi.

The true worms, or annelids, are represented on land by the earth-worms, the land leeches, and the onychophores. Earth-worms are found all over the world, living in burrows in the ground or in decaying material. They swallow earth and pass it through their bodies, digesting out of it some of the organic matter it contains, a manner of feeding adopted by very few insects, though duplicated in the snails. Darwin calculated that there were on an average 53,000 earth-worms in an acre of garden ground, and that they passed 10 tons of soil annually through their bodies. Some earth-worms grow to a very large size, five or six feet in length, but most of them are a few inches long. They furnish food for the young of certain parasitic flies and certain fire-flies and probably also of other predaceous types, for some centipedes, some snails, and the land planarians, for moles and occasionally other mammals, and for various birds, and they are always much infested with internal parasites. The land leeches in the eastern tropics are few in number of kinds, but abundant in individuals in suitable locations, and greedily suck blood. The onychophores are curious worm-like creatures, active at night, which feed on various insects which they catch by spitting liquid silk at them by which they are hopelessly entangled; they live in the tropics and in the southern hemisphere, and for the most part are rare and local.

Closely allied to the insects are the crustaceans, including the lobsters, crabs and similar creatures. The common wood-lice, pill-bugs or sow-bugs, found in rotting wood, under logs, etc., sometimes in ants' nests and in cellars, occur everywhere. They live chiefly on damp decaying vegetable matter. The land crabs of the tropics and some crayfish are almost entirely terrestrial, though not well adapted for terrestrial life. They feed on plants and dead vegetable matter, and sometimes on carrion; one of the best known of these is the famous eastern robber crab which climbs cocoanut trees. As compared with insects the land crabs and crayfish are very large and powerful; but the number of kinds is limited, and most of them do not go very far from water.

Land planarians are abundant in the ground and in protected situations in damp forests in the tropics, whence they are frequently brought into our green-houses. They feed upon earth-worms. A very few sorts of nemerteans live on land; they are all carnivorous.



FIGS. 159–170. Beetles commonly found in houses.

For explanations of the figures see p. xvi.

Abundant everywhere in all situations, free-living or as parasites, are multitudes of nematodes or thread-worms and of protozoans. For the most part these are small and hence not often noticed; but they must not be forgotten.

How can the conditions of animal life on land briefly be described?

Active animal life exists at all temperatures from the melting point of ice, 32°, to about 40° below the boiling point of water, and from an air pressure of one atmosphere to a pressure of about one third of that amount. Below the freezing point only those animals remain active and feed which, like the birds and mammals, create a special temperature in which they live insulated from and independent of that of the air.

All animal life is based upon plant life, for only plants can convert inorganic into organic substance. Insects and their allies represent the major part of animal life on land; they feed on all parts of plants, and on every sort of plant, and are the main support of the other animals which do not feed on plants. The vertebrates form the next most important group, and of these certain types of mammals are the chief plant feeders. The molluscs and the earth-worms are of some importance in the picture as a whole, while the other animal groups are all but negligible.

The vertebrates which are not plant feeders eat other vertebrates and insects, a few the snails and worms. The insects which are not plant feeders eat other insects and vast numbers of them, horse-flies, tsetse flies, stable-flies, mosquitoes, some midges, buffalo-flies, deer-flies, black-flies, sand-flies, and other blood-sucking flies, fleas and jiggers, bot, warble, and other parasitic flies, bugs, biting and sucking lice, horn moths and other moths, mites, ticks, and various other forms, subsist wholly or in part upon the vertebrates.

And within the bodies of all insects, vertebrates and other creatures live hordes of other parasites both animals and plants from which no living thing is ever wholly free.

ANIMAL FLIGHT

One of the most interesting phenomena connected with many of the animals that live on land, as well as some that live in water, is the ability they possess of traveling through the air, and any account of animals, especially of land animals, would be incomplete without a brief description of the very diverse ways in which they do this.

The possibility of passage through the air assists the animals in their struggle for existence in four main ways. Among most insects flight serves merely to distribute the various types more widely and more evenly than would otherwise be possible for these small creatures, thus enabling them more efficiently to make use of the food supply. For instance, you plant some cabbages in your garden. Soon some bright green caterpillars appear upon them. How did they get there? Their mother, a small white butterfly, in flying about discovered them. She was raised on someone else's cabbages, possibly miles away.

The uncountable myriads of insects cruising through the air all summer day and night searching for a place to lay their eggs or for a mate, form an important food supply themselves, as their total bulk is very large, and many birds, like swallows, most bats, and many other insects live exclusively upon them. Hope of escape from enemies alone impels the flying-fish and flying-squid to journey through the air, and many birds use their wings only under similar conditions. Without the power of flight bees could not store their honey, nor could most birds find sufficient food. The food of vultures and the larger birds at sea, for instance, is widely scattered, and to live at all such birds must be enabled to inspect an enormous area each day.

Before taking up flight in detail let us digress a bit and see how the mind of man has been influenced by the sight of birds

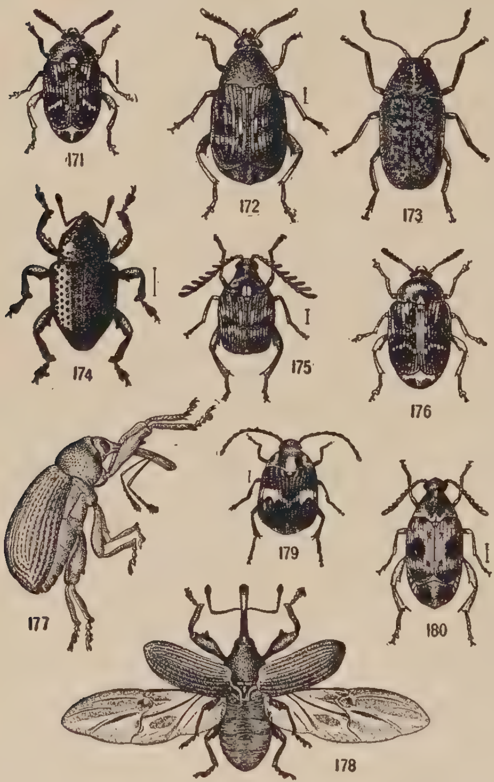
and bats and insects passing easily through the air from place to place. From the very earliest times of which we have a record and among all the human races one of the most strongly marked of human yearnings has always been the desire to fly, to be able like a bird to leave the earth and to soar higher and higher until all earthly things are left behind. This desire to fly is reflected in the folk-lore and stories of all peoples, and to a greater or lesser extent in all religions.

The most conspicuous soaring bird, the eagle, some variety of which occurs almost everywhere, has been adopted as a national, tribal or family emblem to a greater extent than any other animal or object. You all have heard of the American eagle. He figures on the President's flag, on many of our coins, sometimes on our postage stamps, on much of our official letter paper, and on the caps of our army and navy officers. We use the eagle to designate colonels in the army and marine corps, and captains in the navy; and in the army further for all "unattached" officers, and officers of the General Staff. Formerly our generals also wore the eagle, combined with two stars. We used to call one of our coins the "eagle," and more than one hundred of our towns and villages have "eagle" in their names.

While the eagle and the falcon are everywhere associated in the public mind with noble and sublime ideas or aspirations, the creatures that fly by night suggest to all peoples something mysterious and unnatural, and give rise to feelings of awe and dread. The owl is regarded with superstitious fear in many countries, and always is a symbol of something either harmful, or at least uncanny. He is feared or distrusted, but never respected. We speak of people sometimes as "wise old owls," though we never apply this term to those we really hold in high regard.

The bat is the most characteristic and conspicuous of night ranging creatures, and in the day time completely disappears. It is thus quite natural that in the minds of superstitious peoples the bat should be the preëminent symbol of darkness

and of mysterious evil. Malignant spirits and the devil are usually shown with bats' wings in contrast to good and kindly spirits and angels, which are depicted with birds' wings.



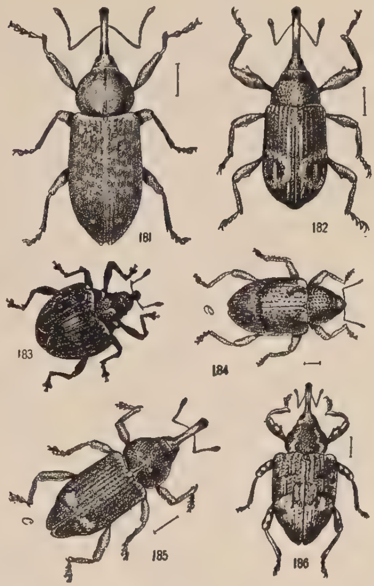
Figs. 171–180. Various destructive Weevils.

For explanations of the figures see p. xvi.

Optimism, or a tendency to look upon the cheerful side of things, is one of the most fundamental traits of human nature. Wherever we have in our language two contrasting words differing from each other in the occurrence or absence of the prefix "un-" meaning "not" this prefix is always placed before a word of good import and never before a word of evil import, showing that our habit is always primarily to contemplate the good and only secondarily to consider the bad in the world about us. This tendency has brought about a curious transformation in the character of one of the oldest and most universally present of all symbolic animals, the dragon.

In all the ancient Asiatic and European civilizations the flying dragon has played an important part. From very early days, perhaps so long ago as 5000 B.C., to the present in

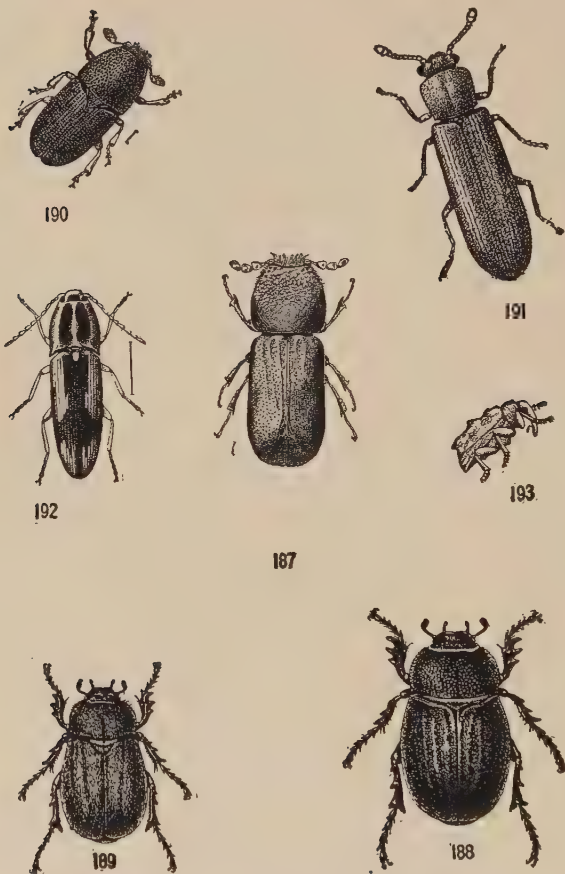
China and Japan, and also in England as shown on the reverse of the British sovereign, the reptilian dragon with its bat-like wings has preserved an astonishing constancy of form. But, as has been pointed out, a curious transformation took place in Asia Minor and the Mediterranean countries, from Babylonia and Egypt through Assyria to Greece. The wings, which at first had been associated with the fore limbs of the typical dragon and had been bat-like, became bird-like, and then were placed on the shoulders of the lion and of the horse, and finally on man himself, as we see on the great columns of the Greek temples of Ephesus. But all these flying animals are historically descended from the same common stock as the dragons of China and Japan and St. George's dragon of England which still preserve the aspect of reptiles. The Bishop of Exeter regards the Hebrew cherubim as probably originally dragons, and the figure of the conventional angel is merely the human form of the dragon.



FIGS. 181–186. More Weevils.

For explanations of the figures see p. xvi.

Besides the eagles, bats and dragons there are many other flying creatures of less, though still far-reaching, significance as symbols. Such are the dove of peace, the rooster, Egypt's sacred ibis, storks and swans, the "quetzal" of Guatemala, and a host of other birds remarkable for their powers of flight or for their beauty. In parts of South America the natives tell you that the gorgeous butterflies called *Morphos* which



FIGS. 187–193. Various destructive Beetles.

For explanations of the figures see pp. xvi, xvii.

are only seen high up among the trees on dying enter the ground and there become preserved as emeralds. Flying creatures, especially birds, butterflies, winged mammals and winged serpents, are familiar subjects for more or less conventionalized designs, especially on pottery and totem poles, and coats of arms, but more or less on all ornamented objects, and on all types of family or individual insignia.

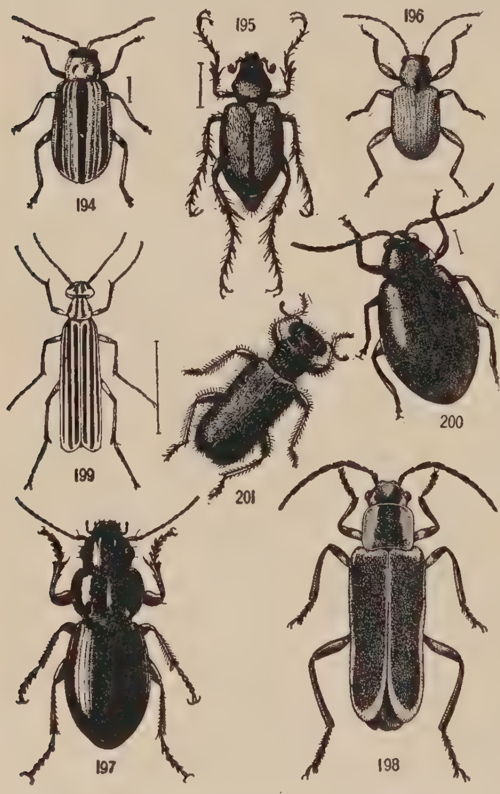
Of all known kinds of animals almost two-thirds can fly, or at least glide through the air, and of land living creatures the flying sorts number about three-quarters of the whole. There are more than 400,000 kinds of flying insects, more than 20,000 flying birds, 600 flying mammals, all but a few of which are bats, possibly 60 flying fishes, and a few flying lizards, snakes, and molluscs, and perhaps frogs and crustaceans.

Of flying creatures some will fly only at rare intervals and under strong compulsion, and others, like the flying ants and termites, while strong fliers, make only a single flight after which they discard their wings by cutting them off with their mandibles or by breaking them off at a line of special weakness and again become ground living. From such as these the amount of time spent on the wing by animals increases step by step until we reach the chimney swifts which fly practically throughout the daylight hours, the insect eating bats which seem to fly most, if not all, the night, and the albatrosses and related sea-birds which in some localities appear to fly for days and nights together without rest.

The birds are the most familiar of the larger flying creatures. Flying birds range in size from the smallest humming-birds, which are much smaller than our common North American kinds, to the South American condor, with very broad wings, and the wandering albatross with very narrow wings spreading eleven feet or more.

It is a curious fact that the larger the animal the smaller in proportion are the wings. Insects have relatively much larger wings than birds, and small birds have relatively much larger wings than big ones. In the mosquito for each pound of body

weight there is a wing area of 4 square yards, 6 square feet and 105 square inches; in a butterfly of average size each pound of body weight represents a wing area of 3 square yards, 8 square feet, and 87 square inches; in the swallow this is reduced to only 4 square feet and 18 square inches, in the pigeon to 1 square foot and 14 square inches, and in the stork to only 122 square inches.



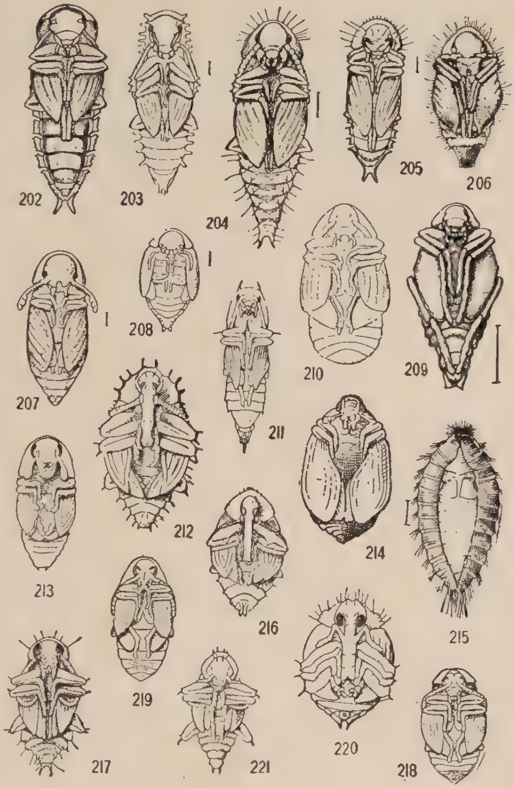
FIGS. 194–201. Some destructive, and some predaceous Beetles.

For explanations of the figures see p. xvii.

Not only do the small birds have larger wings than bigger ones, but they move them much more rapidly. The wings of the smaller humming-birds vibrate so fast that it is difficult for the eye to follow them. The wing beats of the sparrow are 780 per minute, of the duck 540, of the pigeon 480, and of the crow about 120.

It was the necessity of finding answers to these questions, why do small birds have to have larger wings than big ones, and why do they have to move their larger w ings more rapidly, that made the development of the flying-machine so difficult. The wings of many of

the larger birds like the loons and grebes as we see them in the air look ridiculously small, yet these birds can fly for enormous distances at a high speed. It is, however, very difficult for them to get started, and many of them cannot rise from the ground at all.



FIGS. 202–221. Pupae of Beetles.

For explanations of the figures see p. xvii.

Bird's wings perform two functions; they lift the bird and they drag it forward. We all know that if a light object is thrown it will not travel so far as a heavier object thrown at the same speed. A pitcher cannot throw a ball of feathers so far as he can a base ball. If a large and heavy bird can once get going at good speed a relatively small force will keep him going. His body is inclined in such a way that it is kept in the air through its momentum on the principle of a kite. The wings by their motion serve to maintain the speed, but have very little lifting to do. The lighter and smaller the bird the less is its momentum. Lessened momentum prevents it from maintaining its height by inclining its body against the air.

If the wings cease their action the body drops almost instantly. A small bird can approach a perch at full speed and alight upon it with very little voluntary checking of its momentum, but a heavy bird must expend much energy in checking its forward impetus before it can alight with safety. The wings of large and heavy birds serve chiefly to maintain speed, the height being maintained by the momentum and the kiting effect of the body upon the air. The wings of small and light birds must constantly lift as well as maintain momentum — or rather they must constantly lift the bird and pull it forward. This is the reason why the larger the bird the smaller the wings; but the large birds, while they fly with much less effort than the small birds in spite of their smaller wings, have great difficulty in getting started and in stopping. From this it naturally follows that while small birds are found everywhere in all situations, large strong flying birds are mostly confined to the sea and to very open regions where they can arise and alight with safety.

The speed at which birds fly varies very much, but it is not so great as is commonly supposed. You can easily prove this for yourself by pacing them in an automobile along a country road. Only a few birds can fly as fast as the fastest express trains, and none can go so fast as the speedier aeroplanes. Wild ducks and geese have been found to travel on their migrations at a rate of between 44 and 48 miles an hour. Homing pigeons usually travel at between 50 and 55 miles an hour. While some swifts may attain a speed as great as 100 miles an hour, most of our smaller birds fly at a rate of between 25 and 28 miles an hour, or at about the average speed maintained by an automobile.

The power of flight and the possibility of moving rapidly from place to place high above such obstacles as water, trees, fences, hills, etc., permits the birds to wander about from season to season, visiting now one region now another in search of food. In the autumn many of our common birds, like the swifts, the swallows, the flycatchers and the warblers disappear

to the southward, and other birds from the north, like the northern chickadees and nuthatches, the crossbills, and the pine and evening grosbeaks, appear in the places they have left. Some birds, like the robin, do not go very far, wintering chiefly in the southern states. Many go to Central and South America, while a few travel enormous distances. The Golden Plover, which nests in the extreme north of North America, winters in the south of South America. This bird after leaving Labrador ordinarily does not come down again until it arrives in Guiana, more than 1700 miles away. It is frequently seen passing over the easternmost of the West Indies at an immense height, and has also been seen high in air several hundred miles east of the Bermudas. Coming north it takes a different route, up the Mississippi valley. The Eastern Godwit, a plover-like bird which nests in Alaska and in eastern Siberia, spends the winter in New Zealand. A great many apparently feeble birds can cover enormous distances without alighting. The little Sora rail can cross the Caribbean Sea twice a year without difficulty, and two sorts of cuckoos pass every year from New Zealand to New Caledonia and back over 1000 miles of sea. In many places it is still erroneously believed that the small birds get about by simply perching on the backs of larger birds and being carried by them, so incredible do such powers of flight appear in such weak creatures.

The height at which birds migrate varies considerably. From measurements taken on birds as they crossed the face of the moon at night it was found that the migrations in May were at a height of from 1200 to 2400 feet, and those in October at between 1400 and 5400 feet.

The flight of birds may be roughly divided into three types, ordinary flight, with almost innumerable variations, such as we see in the common land birds, soaring, and gliding. In the usual type of flight the bird moves through the air with a continual motion of the wings. This is the only type of flight possible in still air, and is characteristic of most land birds, all the smaller sea birds, the ducks, geese, herons, and many others.

The large birds progress ordinarily in a straight line, with a slight raising and lowering of the body at every wing beat if the flight is slow, as in the herons. Their momentum and the kite-like effect of their heavy bodies tend to keep them up, and they are very careful not to lose altitude on account of the great difficulty they experience in rising again. Most of the small birds have a wavy or undulating flight which is especially well seen in the finches and the wood-peckers. The rapidity with which they descend when the wing beats cease shows how slight their momentum is, and how essential for them is the great development of lifting power.

Very many of the larger broad winged birds, as hawks, eagles, vultures, ravens, pelicans, cranes, spoonbills, screamers, herons, etc., are able to circle on motionless wings, gradually rising higher and higher, until they almost or quite disappear. These birds are large and heavy, and compared with small birds their wing area is relatively less. How do they do it?

Birds seldom soar in cloudy weather, or in cold regions, or in the winter. Soaring is only possible when the earth is heated by the sun's rays. When the earth is heated the warm air just above it rises, and if the heating is intense and long continued strong columns of air rise for very considerable distances, especially over small hills. In these ascending columns of air the birds find a breeze of considerable strength blowing directly upward the force of the ascending air being sufficient not only to keep them up but to enable them to glide continually downward, yet at the same time rise.

Birds soar in circles in order to keep within the ascending column of air; if they fall over the edge of the column they begin to flap in order to get back into it again. You sometimes see a hawk do this. Soaring is a very popular pastime of the large birds in the drier regions of the tropics, and in some places, as in Egypt, hundreds of birds of many sorts may frequently be seen soaring together. One of the most expert of the soaring birds is the great clumsy looking adjutant of India, which by many is supposed to sleep while soaring. In

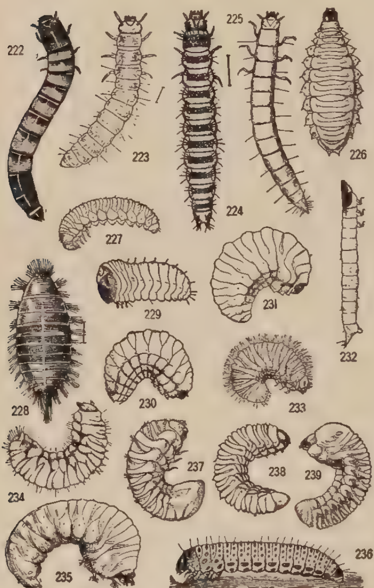
the warm regions the appearance of clouds which obscure the sun promptly weakens the force of the ascending columns of air and soon cause all the soaring birds to flap and to return to the ground. With us in the north only a few birds, mostly eagles, hawks and vultures, soar, and these only on warm, bright and sunny days.

Many birds, such as partridges, pheasants, quail, tinamous, etc., when startled fly diagonally upward with great violence to a considerable height and then glide downward to a place of safety, and most of the larger birds glide more or less when approaching the ground or a perch. This gliding has been developed not only in the direction of soaring as just described, but also into a combination of gliding and soaring — mostly gliding — which is characteristic of the flight of a very large number of sea birds. Many of these are such adepts that they can glide all day and never flap their wings. The albatross is the most marvellous of all the gliders; he courses back and forth over the waves, always keeping close to the water, for hour after hour with his long narrow wings extended almost motionless.

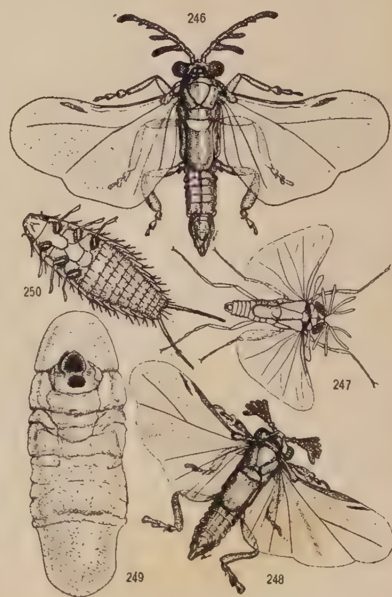
Waves are rows of little hills stretching across the wind. The wind on striking one of these rows of hills is deflected upward with considerable force, and it is by taking advantage of these strong updraughts that the albatross is able to glide perpetually. When flying with the wind the albatross rapidly loses altitude, so he must frequently turn back into the wind again to allow the updraughts from a few waves to raise him anew to the required height. His course to leeward, or down the wind, is therefore a series of loops with long gliding intervals between, and his course across the wind is a similar series of loops. As a steamer plows its way along, the air behind it is drawn under the stern with such force as to rise into a column of considerable height just behind it. On this column the albatrosses frequently balance themselves, appearing perfectly motionless except for the movement of their heads, traveling at the same rate as the ship, being kept up and

drawn along through power originating in the engines of the ship itself. Other sea birds, especially gulls, are fond of balancing themselves on this air column.

In a dead calm the albatross is a pitiable object. He sits on the water, rarely attempting to fly. He can only rise with the



FIGS. 222–239.
Grubs of various Beetles.



FIGS. 246–250.
Some Strepsipterans.

For explanations of the figures see pp. xvii, xviii.

greatest difficulty after a prodigious amount of splashing and flapping, and his very slow, heavy and laborious progress is by an alternation of clumsy flapping and gliding, suggesting the flight of an awkward lazy pelican, of which he soon tires; in fact he is all but helpless. The albatross, the most wonderful flier among the birds, is kept in the air not by any efforts of his own, but by a combination of strong wind and waves, and

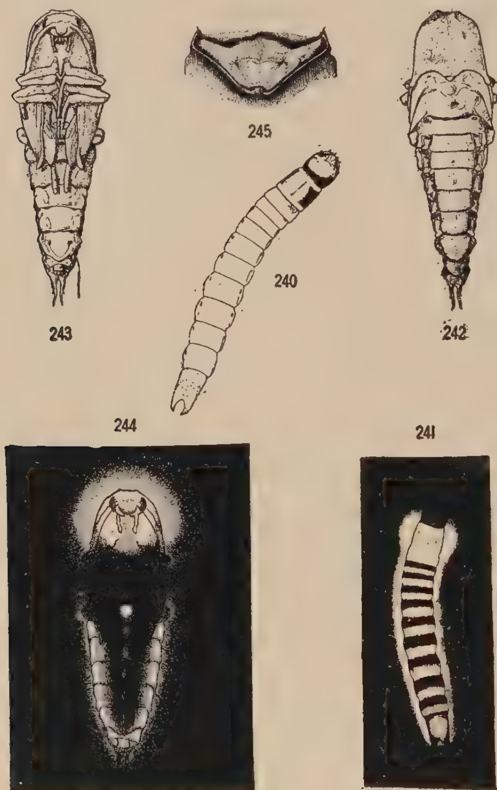
hence the albatross is exclusively a bird of the windier regions of the oceans. He can only exist where the wind is always strong and the waves are always high. The calm belts of the tropics form an impassible barrier for him, and he cannot fly for any appreciable distance over land. The stormy southern oceans and the equally boisterous north Pacific are his home, but no one kind exists in both these places. He cannot live in the tropic calms, nor in the relatively calm North Atlantic.

Quite a number of smaller sea birds ranging in size from the giant fulmars down to the smaller shearwaters have the same habit of flight as the albatross, and are quite as good fliers as is he; but for the most part they are smaller with broader wings and can fly well in winds so light that they would not serve the albatross at all, and they can also fly well, though with much flapping, during calms.

When a strong wind strikes a cliff a considerable amount of air is deflected upward forming a column or wall of air for a considerable height above the top of the cliff. Such a mass of rising air is favorite play-ground for birds which soar above it just as other birds do in the columns of warm air rising from the hot tropical lowlands. At Agattu Island in the western Aleutians where the sun very rarely shines — there is no record that anyone ever saw the sun there — but where the wind always blows there is a cliff near the anchorage on and near which all sorts of birds abound. When the wind blows against this cliff the air above it becomes filled with birds, some merely flying back and forth, like the puffins, murres and guillemots, but others wheeling and soaring like hawks. Most conspicuous among these soaring birds are the geese, cormorants and ravens, birds which ordinarily we never think of as indulging in diversions of this nature. The gulls, too, are very numerous, but as the gull is an expert balancer and glider it seems only natural that he should be here.

In mountainous regions there are always strong updraughts of air, both because of the upward deflection of the winds and because of the warming action of the sun's rays. Mountainous

regions therefore are especially adapted to the development of the soaring habit. The uprush of air due to deflection of the winds makes soaring possible on cloudy days, and in the far north and south under conditions which would prevent it on flat land where the only updraughts are the result of heating.



FIGS. 240–245. Early stages of West Indian Fire-flies.

For explanations of the figures see p. xviii.

Mountainous regions always harbor many soaring birds. As a fruit-eating bird would derive no advantage whatever from the practice of soaring, all fruit being far more visible from below or from the side than from above, and also stationary, the soaring birds of mountainous regions are mostly predaceous or carrion feeders, or a combination of the two, or quite omnivorous. They include eagles, vultures, hawks and ravens, and because of the great advantage that they have in being able with a minimum of exertion to survey a vast amount of territory and thus to detect a maximum amount of food, the largest of the

flying birds, such as the condor, the Californian vulture, the lämmergeier, the griffon and brown vultures, all the larger eagles and the ravens live in mountainous lands.

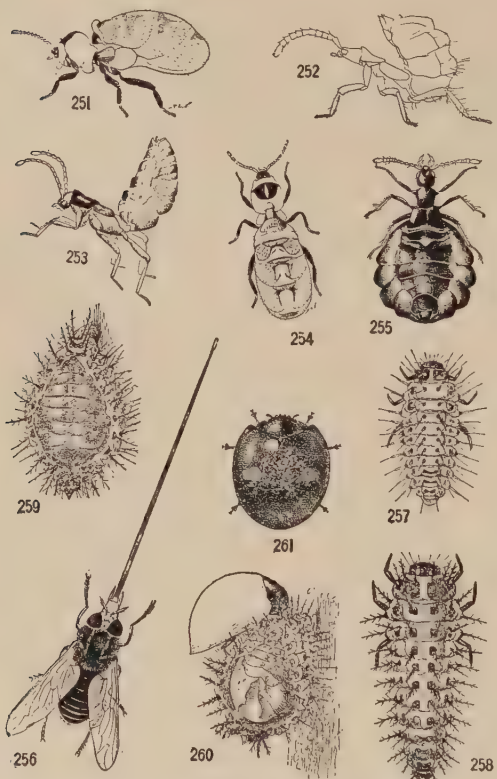
The buoyant effect of wind blowing against a hill side is easily appreciated by watching a turkey buzzard quartering back and forth in his peculiar see-sawing way without flapping his wings, yet without losing altitude.

Among the birds we find all possible gradations from birds like the albatrosses, frigate-birds and chimney swifts, which are almost always on the wing, through the majority of flying birds to such forms as the tinamous and rails which very seldom fly, to others, like the ostriches, that cannot fly at all, and finally to those queer fossil birds with no trace of wings whatever.

The flightless birds fall into three categories. First, birds large, powerful or swift enough to outfight or to outdistance any enemies, like the ostriches of Africa and Arabia, the rheas of South America, the emus of Australia, and the cassowaries of Queensland, New Guinea and the Moluccas. Second, sea birds frequenting regions where there are no beasts of prey, like the penguins, the great auk, and the flightless cormorants of the Commander Islands and the Galapagos. Third, land birds living in regions from which predaceous beasts are absent, such as the dodo of Mauritius, the solitaire of Rodriguez, the kiwis of New Zealand, the flightless rails of Oceania, etc. Unless protected by most rigid laws such birds are doomed whenever man penetrates their territory; if large they and their eggs are eaten, and if small they soon become the victims of the dogs, cats and rats which man always carries with him in his wanderings. Thus the Commander Island flightless cormorant, the dodo and the solitaire, and the great auk have disappeared, and some of the other flightless birds are much reduced in numbers.

The penguins of the southern hemisphere and the great auk have their wings so modified as to form long and powerful fins with which they swim, after the manner of sea-turtles, and

contrary to the habit of most water birds which swim with their feet only, the wings being used but little if at all. The rheas are peculiar in sometimes running with one wing raised like a sail, no one knows why. The ostriches flap both wings in running more or less. In the emus, cassowaries and kiwis the wings are extremely small.



Figs. 251–261. Ant "guests," a Lady-bird, and a Pangonid Fly.

For explanation of the figures see pp. xviii, xix.

The ducks, geese, swans and flamingos for part of the year are flightless, for when they moult all of their wing feathers are lost at the same time, not one by one as in the case of other birds, and they cannot fly until these grow out again. But as these birds are inhabitants of vast marshes, swamps, lakes, isolated reefs and islets, or remote regions where their enemies cannot follow them they do not suffer from the temporary loss of flight.

The bats vary much less in bodily form and in the shape of their wings than do the birds, and their flight is much more uniform. None of them soar, and none of them glide. Unlike

birds, most of them are all but helpless on the ground, though a few of the small ones can run almost as rapidly as mice. Certain of the smaller bats with long and very narrow wings fly so much like chimney swifts that they are easily mistaken for them, and the resemblance is heightened by their somewhat similar chatter. The largest bats, the flying-foxes and other fruit bats, fly like crows.

Nearly all bats, though not rapid fliers, are wonderfully quick on the wing, twisting and turning and even doubling in their flight with an agility rarely seen in birds. For most of them the object of their flight is the same — to enable them to capture insects. Some of them, all large slow-flying ones, eat fruit, one, also large and slow flying, catches fish, while a few others catch small birds or suck the blood of the larger animals. But the great majority feed on insects, and so the same style of flight is equally suitable for all and there is no need for them to specialize as the birds have done. Soaring and gliding would be of no advantage to the bats, for they must seek their food in those still and quiet regions where night insects fly the thickest; ability to turn quickly is their chief requirement. Most bats fly between 10 and 20 feet above the ground, high enough to avoid the bushy and herbaceous growths, and low enough to bring them within the region most frequented by night flying moths and beetles. They avoid the forests, but are abundant in clearings, in open glades, and on the borders of woodlands. The large fish eating bats fly just above the surface of the sea like petrels, coursing back and forth in their search for small fishes. In the day time the bats mostly retreat to the dark recesses of caves or hollow trees, or enter barns or houses, though some of them, like the flying-foxes, suspend themselves from the limbs of trees. Their enemies are few; they are sometimes caught by hawks and owls, and a few small hawks mainly feed upon them.

In the past there lived numerous reptiles with bat-like wings called pterodactyls. These were of a great variety of sizes, from smaller than a sparrow to huge creatures with a spread

of twenty feet or more. Their long jaws were armed with formidable teeth, and they must have been very uncomfortable creatures to encounter. All of the remaining sorts of flying animals except the insects are gliders with the surface of the body increased in various ways so that they are able greatly to prolong their leaps by supporting themselves upon the air. Except for the fishes these are all climbing animals inhabiting the forests, and except for the reptiles they are active only at night. The reason for this is that in order to glide successfully they must attain a considerable height, and during a long glide they are practically helpless; they cannot dodge about and twist and turn as do the birds and bats, so that if they came out in daylight they would run great danger from the hawks.

One of our very common animals, though one not often noticed because of its strictly nocturnal habits and on account of its small size, is the little flying squirrel. Flying squirrels live everywhere in northern forests, in North America, in Europe and in Asia, and in the East Indies some are found which are almost as large as cats. In the flying squirrels the skin along the sides of the body is extended outward in a broad flap stretching from the fore to the hind legs and supported by a long bone arising from the base of the hand, and the tail is flattened and very dense instead of rounded and loose as in the other squirrels. Supported by these strips of skin the flying squirrels are enabled to make enormous leaps from tree to tree, covering sometimes as much as one hundred feet; but on the ground they are clumsy and awkward.

Our flying squirrels are so retiring and so small that in many of the places where they are commonest only a very few people know of their existence. They spend the day in holes in trees from which they emerge only after sunset. But they are rather sensitive, and they usually may be frightened out of their holes by tapping the trunk of the tree in which they live. However, it is one thing to get a flying squirrel out into the open, and quite another thing to catch him. He comes from his hole like a flash, climbs to the top of the tree, keeping the trunk between

himself and the observer, and launches out into the air. At first he falls diagonally and usually quite abruptly downward, his course gradually curving outward until his body is parallel with the ground, when he suddenly shoots upward and lands on the trunk of another tree, instantly disappearing around the trunk and mounting to the upper branches either to hide or to launch forth again. He is an expert in the art of keeping a tree between himself and his pursuer, and because of the difference in color between the upper and under sides of his body he sometimes seems in the mottled shadows of the woods to disappear while in full flight. As he is not very much larger than a mouse he can hide very easily, and altogether he is quite an elusive creature.

In the forests of the East Indies there lives the flying maki, or *Galeopithecus*, an animal very different from the flying squirrel, but resembling it in its gliding flight. The parachute like extensions of its skin are relatively larger than those of any other gliding animal, and it is able to "fly" for more than two hundred feet.

New Guinea and Australia, especially New South Wales, are the home of the flying opossums, some of which are among the smallest of all known mammals measuring scarcely five and a half inches in length with the tail making up more than half of this. These little creatures are more expert on the wing than the flying squirrels or the flying maki, and are able to twist and turn to an astonishing degree. The great forests south of the Sahara are inhabited by the flying mouse, a little creature with the habits of the flying opossums.

In the East Indian region are found the flying lizards. These are rather small lizards with a broad thin semicircular projection like a broad fin stiffened by processes from the ribs on either side of the body by means of which they are enabled to glide through the air after the manner of the flying squirrels. Like the flying squirrels they glide obliquely downward until near their objective, when they turn and finish their flight with a short upward glide.

Some of the Malayan geckos or singing lizards have the body expanded somewhat after the fashion of the flying lizards, but the expansion is not stiffened. These have been supposed to fly, but Dr. Stejneger believes that the broadening is merely an adaptation for concealing them by obscuring their outline and that they cannot really fly.

Certain climbing snakes of the Maylayan archipelago are able without any special adaptations of the body to glide through the air like a missile from one tree to another over a considerable distance. These flying snakes have the under side of the body marked with deep longitudinal grooves, and during the leap they hold themselves motionless like a rigid stick. In the forests of Sumatra, Borneo and Java there lives the flying frog, a sort of tree frog with especially elongate toes and fingers between which are greatly developed webs. In jumping from tree to tree this frog is said to spread its feet and thus to glide on the expanded membranes much after the manner of the flying squirrels, covering enormous distances. Most tree frogs are prodigious jumpers, and there seems to be some doubt whether this one is really helped much by its large feet.

We all know that certain kinds of animals are only found in certain regions of the world, tigers only in Asia, giraffes and zebras only in Africa, kangaroos only in Australia, musk oxen only in the arctic regions, armadillos and sloths only in tropical America, etc. In the same way certain habits affecting many kinds of animals may be confined to particular localities, Terrestrial flying creatures other than insects, birds and bats are almost exclusively confined to the East Indian region, where we find flying squirrels, flying makis, flying lizards, flying snakes and flying frogs. Outside of the East Indies there are only three types of flying animals, the flying squirrels of Asia, Europe and North America, the flying opossums of Australia and New Guinea, and the flying mice .of Africa, only one sort of flying creature in each place. Except for birds and bats and insects there are no flying animals of any kind in South America.

But on the other hand the habit of hanging by the tail and of using the tail as an organ of prehension and of locomotion is almost exclusively confined to tropical America where it is characteristic of many animals in many very diverse groups, as monkeys, carnivorous animals, opossums, rats and porcupines. Why should this be so?

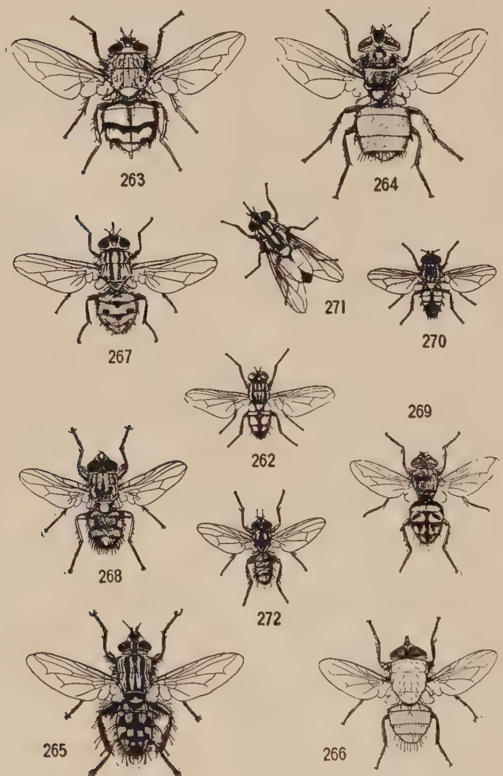
Let us now briefly survey the insects, the most numerous by far of all the flying creatures. In their younger stages all insects are wingless, but when adult most insects can fly. Of all of them the tsetses and some of the bird flies fly the longest in proportion to their length of life. These flies are born as pupae or as larvae just ready to transform to pupae from which adults emerge. They do not feed as larvae or as pupae, and their adult winged existence is correspondingly prolonged.

In many insects the flying stage is very short. For instance the seventeen year locust, or "periodical cicada" as the entomologists would prefer to have us call it, spends only about one nine hundredth part of its existence in the winged state, and it does not fly much even in that short time; while in some may-flies, which lack a mouth and therefore cannot feed, the flying period is less than one one thousandth part of their whole life. Thus if we were may-flies flying would be possible for not more than twenty-five days out of a normal life.

In most insects the flying stage is rather short compared with the whole length of life, and in very few is it so much as a quarter of their whole existence. Also, in most flying insects both sexes fly equally well, as among the birds and bats, but in many the larger and heavier females are much less expert than the males, and in some the females cannot fly at all, the wings being much reduced in size or even absent altogether.

Let us here repeat that the relative size of an insect's wing is much greater than that of a bird's wing. An insect is so light that it has no momentum, so that the wings must continually pull the body forward as well as lift it. Since there is no momentum the lifting and the pulling must be as nearly continuous as possible, so that the wing motion of insects is

incomparably more rapid than that of birds. The common cabbage butterfly moves its wings at the rate of 540 strokes per minute; the sphingid moths at the rate of 4,320 beats per minute; the wasp at the rate of 6,600 beats per minute; the honey bee at the rate of 11,400 beats per minute; while the wings of the common house-fly vibrate at the rate of 19,800 beats per minute.



FIGS. 262–272. Flies commonly found in houses.

For explanations of the figures see p. xix.

The difference in the relative area of the wings between a mosquito and a stork may be appreciated when it is realized that if a stork had wings proportionately as large as those of a mosquito they would have an area of almost twenty-eight and a half square yards, and an expanse of more than twenty-five feet.

Of all the insects the larger dragon-flies, so common about the ponds and streams in which they live when young, are the swiftest on the wing. One sort of these (*Austrophlebia*) was timed by Dr. R. J. Tillyard, who found that it covered between 80 and 90 yards in

three seconds, which means that it was flying at the rate of nearly 60 miles an hour.

Dr. Alexander Wetmore has recently determined that the great blue heron flies at the rate of 28 miles an hour, the red-tailed hawk at 22, the flicker at 25, and the raven at 24, so it is evident that the larger dragon-flies have little to fear from birds, though many of the smaller, weaker ones are eaten by them.

Such birds as travel at a rate approaching that of the large dragon-flies often become victims of their speed. Being heavy, they cannot turn aside to avoid danger; put a net suddenly in front of them, and into it they go.

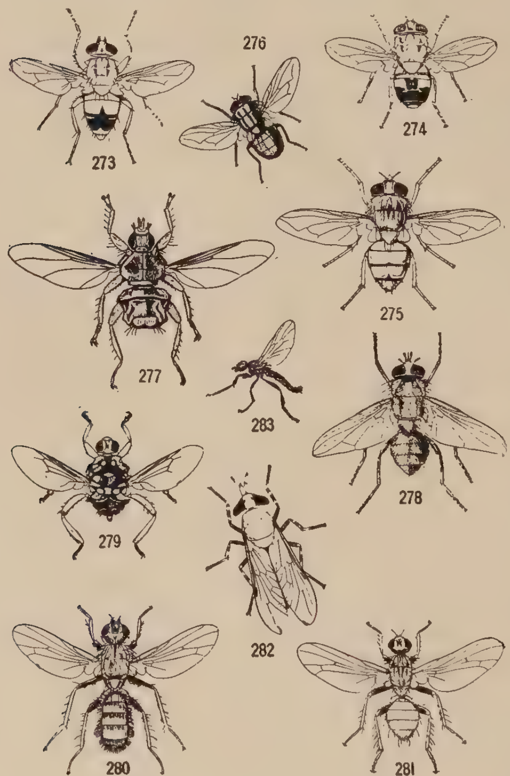
The Esquimaux catch thousands of sea birds annually in this way by intercepting them as they fly along the shore. But the dragon-fly is different. Put a net in front of him and he instantly shoots off sideways, or up or down, or even doubles on his course. He is so light that he has no appreciable momentum and therefore he can twist and turn about in a way quite impossible for any bird.

There are many different kinds of dragon-flies; all of them eat other insects which they catch upon the wing. They have many different kinds of flight, darting, skimming or soaring about in search of their more or less nimble victims. But the soaring, so-called, of a dragon-fly is a very different thing from the soaring of a bird; at first sight it seems to be the same, but if you watch closely you will see that the dragon-fly keeps his wings in motion almost all the time.

Dragon-flies have various relatives, like ant-lions and lace-winged flies, which, strange to say, are slow and feeble fliers, they are awkward and clumsy in the air and they give you the impression that their wings are too big for them. The dragon-flies and their relatives are the only flying creatures which have two functional pairs of wings acting independently and placed one behind the other as in the original Langley aeroplane.

The beetles, like the dragon-flies, have two independent pairs of wings, but the wings of the anterior pair are modified in such

a way that when the beetle is at rest they fit closely down over those of the posterior pair, which are folded up beneath them. In flight these anterior wings are held rigidly extended at various angles, the hinder wings doing all the work. It is possible, however, that in some cases the anterior wings may serve the purpose of a pair of planes, assisting in keeping the insect in the air, though many beetles fly just as well if they are removed, and in some excellent fliers, like the devil's coach horse, they are so small as to be quite functionless.



Figs. 273–283. Various Flies.

For explanations of the figures see pp. xix, xx.

As a rule the flight of beetles is slow and clumsy, especially of the larger kinds which fly only at night and rather high so as to avoid the shrubs and bushes. Some, like the tiger beetles which in the spring we see running rapidly about on the bare ground in their hunt for smaller insects, are quite expert in turning and twisting in the air, while very many cannot fly at all. The grasshoppers, locusts, crickets and their allies have the fore wings stiff and tough, not used in flight,

and the hind wings membranous and closing like a fan instead of being folded on a hinge in the front margin as in the beetles. In most the flight is weak and rattly, and very many cannot fly at all. But some, like the migratory locusts, are strong fliers.

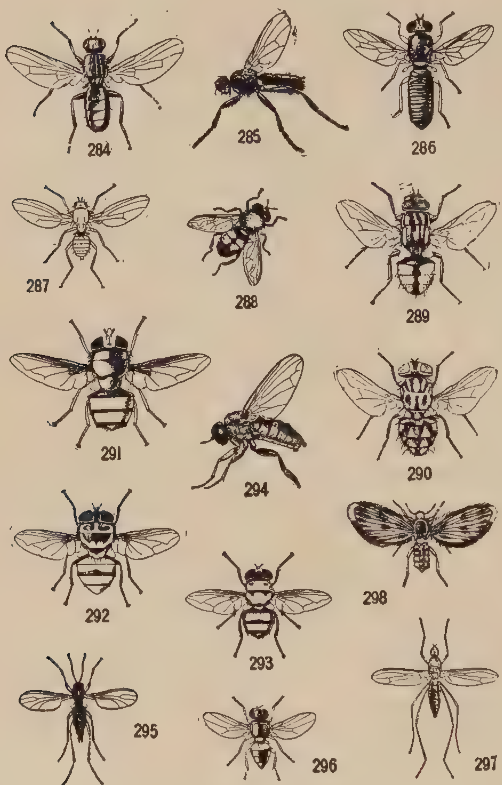
Regarding the speed of grasshoppers I quote a letter from Mr. Andrew N. Caudell.

"In early August of 1920 while studying economic species of grasshoppers in Centennial Valley, Montana, I had an excellent opportunity of observing the speed at which *Cannula pellucida* flew. By noting individuals that were flushed by the roadside by the automobile in which I was riding I chose ones that flew parallel with the machine, which was driven at the rate of 15 miles per hour. I found that under those conditions the rate of flight for this species is almost exactly 15 miles per hour. In long flights, especially with the wind, the rate may be much faster, as J. R. Parker has estimated the speed of migratory swarms to be 30 miles per hour. That appears to be too high an estimate, judging from my experience with the insects' flight when flushed by the automobile. Mr. C. L. Corkins gives the rate of flight of *Melanoplus atlantis* as 20 miles per hour, the rate being determined by the same method I used with *Cannula*, that is by observations made from an automobile moving at a given rate."

The flies properly so called, the house-fly, the blue-bottle, the horse-fly, the crane-fly, the black-fly, the mosquito, the gnat, the midge, the robber-fly, etc., have only two wings, the hinder pair being replaced by curious knobbed structures known as balancers or halteres which are apparently sensory and in some kinds possibly stridulating. It is interesting to note that while in the beetles the hind wings only are used for flight, in the flies these have completely lost their function as flying organs, the flight being effected entirely by those of the anterior pair.

While a few flies are wingless, or have very small and useless wings, most of them are expert fliers. They can twist and turn and dodge and hover and dart quite as well as the dragon-flies,

and though most of them are not very speedy some, like the robber-flies which feed on other insects, are by no means slow. There are more different kinds of flight among the flies than among any other kinds of insects, ranging from the direct, swift and powerful flight of the robber and horse-flies and the twisting and dodging flight of the lesser house-fly to the dancing of the gnats and the hovering and darting of many syrphids and bombyliids. These last are commonly seen suspended and apparently motionless in the air a few feet above the ground over woodland paths; if startled they dodge away so rapidly that frequently the eye cannot follow them.



FIGS. 284–298. Various Flies.

For explanations of the figures see p. xx.

In most other insects the four wings when extended function as a single pair, the hinder edge of the fore wings being hooked to the front edge of the hind wings in various ways, as in the butterflies, moths, bees, wasps, etc. In some of the butterflies and moths the wings are enormous in proportion to the size of the body.

Many syrphid and bombyliid flies, some horse-flies or tabanids, the hawk-moths and the humming-birds, all of which hover in the same way, are able to fly backwards slowly, reversing the action of their wings. You can see a humming-bird do this as he goes from flower to flower.

Very few insects have a definitely developed tail capable of being used for steering; some of the hawk-moths have moveable tufts of long hairs on the end of the body which may be used for this purpose, and one of the small parasitic wasps has a very remarkable tail of two thin plates crossing each other at right angles in the middle. Many butterflies, like the swallow-tails, and a number of moths, like our common luna and its various Asiatic relatives, have the hind wings produced into so-called tails, which may be very long; in some species only the males have them. In other insects, as in certain ant-lions, the fore wings may be normal, but the hind wings are very narrow and extremely long, and more or less twisted.

In all flying animals the steering is done chiefly or entirely with the wings. Many bats are tailless, but they fly quite as well as the bats with tails. The long-tailed birds, like the cuckoos, forked-tailed, scissor-tailed and paradise flycatchers, long-tailed trogons, tailor-birds, emu-wrens, lyre-birds, turkeys, curassows, pheasants, etc., are relatively weak fliers, while all the birds remarkable for very long flights, like the plovers, curlews, godwits, ducks, geese and swans, or for long continued gliding flight, like albatrosses and shearwaters, are short-tailed. Soaring birds to increase the lifting surface mostly have large broad tails, just as they have very broad wings. Most long-tailed birds are small; if large they are ground living; if good fliers the elongated feathers of the tail are reduced to two which are usually very narrow, the two outermost in the swallows, terns, some flycatchers, some humming-birds, etc., the two central in the macaws, lories, tropic-birds, other flycatchers, other humming-birds, etc. Birds which pounce upon their prey or feed after the manner of bats, such as most hawks, falcons, kites and owls, goatsuckers, night-

hawks, whip-poor-wills, most flycatchers, etc., have large broad tails, and undoubtedly these assist them in turning abruptly downward, upward or sideways.

Most creatures when flying make more or less noise, and many have special sounding organs connected with their wings, The bats all make a low swishing sound which is only audible for a short distance. The wings of most birds make a swishing sound which varies from the droning hum of the humming-birds to the loud dull rustling roar of the large vultures, swans, geese and ducks. These sounds are merely the result of the rapid passage of the wings through the air. In some ducks, on that account commonly called "whistlers," the wings make a loud shrill whistling noise in flight which on a still day may be heard for a very considerable distance; this is due to the vibration set in motion by parts of certain of the wing feathers. The passage of most pigeons and doves and of some other rapid fliers through the air is also accompanied by a more or less distinct whistling. In addition to this pigeons and doves on rising suddenly from the ground usually make a clapping or rattling noise with their wings; but if not startled they often rise quietly. The flight of some birds, especially of the owls, is strangely silent, apparently so as not to interfere with the detection of the slight sounds made by the creatures they are seeking, by which means they find them.

The droning of beetles and the buzzing and humming of flies, bees, wasps, mosquitos, etc., are known to everyone; some insects, like the large cockroaches in the tropics, fly with a loud rattling noise, and some, like certain butterflies and grass-hoppers, when on the wing make chirping or clicking sounds at will by means of a special mechanism connected with the wings.

The flight of the large slow flying moths, like our common cecropia, polyphemus, promethea and luna, like that of the owls, is almost noiseless; and it is fortunate for them that this is so as otherwise they would soon disappear through extermination by small owls and by the bats.

Many flies can hum or buzz quite as well with the wings cut off as with them present, apparently through the action of the halteres which in this case appear to be wings transformed into singing organs.

The song of the crickets, locusts, grasshoppers, katydids and similar insects is produced by the fore wings, parts of which are modified into very perfect sounding organs operated by the rubbing of the wings together, or by the long hind legs.

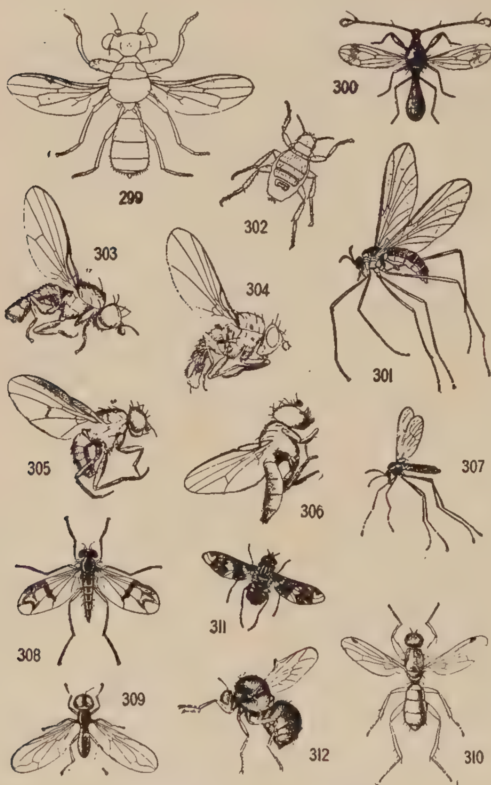
The song of the cicadas and their allies, though it sounds much like that of the crickets and the locusts, at least like that of some of their tropical representatives, is not produced by the wings but by a special apparatus on the under side of the body. In some kinds the piercing shriek they give can only be compared to the whistle of a steam engine, and may easily be heard on a calm day four miles or more.

The wings of insects are mere outgrowths from the body wall, quite unconnected with the legs. They are thus comparable to the side extensions of the flying lizards and to the cobra's hood. In many groups, especially in the moths and butterflies and in many flies, like moth-flies, they bear numerous broad scales somewhat resembling the feathers of a bird; in others they are often sparsely hairy like a bat's wings.

Except for bats all the flying mammals are tree-living climbing creatures, and in them the wing membrane is stretched between the legs.

In the bats and birds the wings are an adaptation from special climbing organs, somewhat as suggested by the long arms of the spider monkeys. In the bats the flying surface is formed by broad areas of skin stretched between immensely elongate fingers and extending to the hind legs as in the ancient flying reptiles and in all the other flying mammals. In the birds the flying surface is made up of long feathers which are outgrowths of the skin of the long front limbs. With their very long arms the monkeys and the lemurs climb with great rapidity through the forest trees. With their very long and suitably modified front limbs the bats and birds in much

the same way climb through the air. One bird, the hoactzin, when young climbs actively about the bushes with its fore limbs which, as in many other birds, have claws; when fully grown it climbs through the air like any other bird.



FIGS. 299–312. Various Flies.

For explanations of the figures see p. xx.

The wings of flying fishes do not differ from the corresponding fins of other fishes except in their greater size.

Besides the animals which fly by their own efforts there are many others which at some period of their existence, usually when young, are wafted through the air without the aid of flying organs just as the seeds of many plants are blown about.

Chief among these are the flying spiders. Many different kinds of spiders have hit upon this means of getting from place to place. It is usually, though not invariably, the young spiders that do this, and the phenomenon is best observed on warm and comparatively quiet autumn days when there is a good updraught of wind. The spiders climb to the summit of some object, such

as a stick, fence post, plant or stone, and release a fine thread or several of them, or sometimes a tangled mass of threads. When the pull of the ascending air upon the threads is strong enough the spider lets go his hold and floats away. One of the most sedentary of the spiders, living as a rule under stones, sticks and other objects, has adopted this means of getting from place to place, and it is also used by spiders of many other kinds. Occasionally spiders try to rise in an adverse wind, and then their threads instead of rising are blown onto the ground or onto the nearby plants sometimes forming enormous sheets of silk. These sheets of silk may later be lifted up and blown away, coming down in some distant place as a so-called gossamer shower.

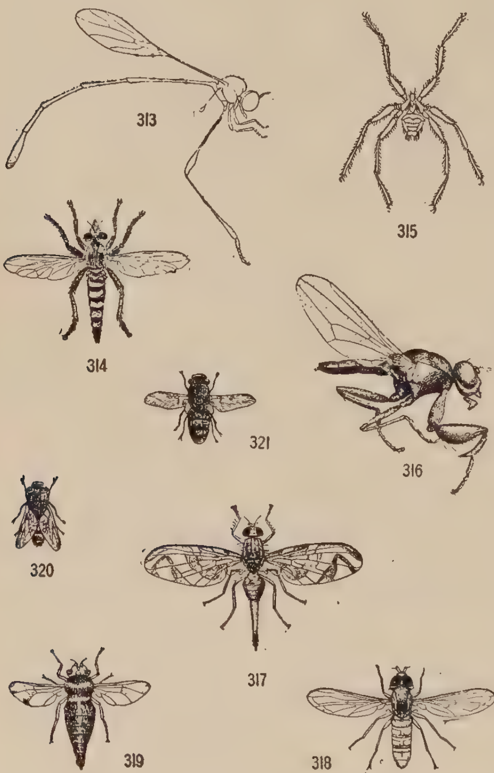
Many insects, especially the smaller ones like aphids, can fly just well enough to keep up in the air without making much of any progress. These form a connecting link between creatures that fly by their own efforts and those that are wafted by the winds from place to place.

Many caterpillars, such as those of the gypsy moth, are, when very small, widely distributed by the strong winds of spring.

When a pond dries up many of the small water creatures either condense themselves into the smallest possible space and surround themselves with a tough shell, or form highly resistant eggs and die. These capsules and eggs are picked up by the wind and carried for long distances; in fact the air, even for hundreds of miles at sea, always contains besides mineral dust, particles representing the remains and the living spores and seeds of animals and plants. This is why any puddle of water, no matter where it is, on the ground, on a roof, or in hollows in the branches of tall trees, swarms with life almost immediately after its appearance.

Among the animals on land which do not fly, many of the larger ones have certain adaptations which enable them to use the resistance of the air for their protection. Leaping animals that live in tree tops, like the lemurs and the smaller monkeys

and most squirrels, very often have great outgrowths of long hairs which serve as brakes and serve to minimize the shock of landing. The so-called flying-monkey of the upper Amazons looks when it leaps much like a flying squirrel, but it has no extended membranes on its sides, great tufts of long hair simulating these.



FIGS. 313–321. Various Flies.

For explanations of the figures see p. xxi.

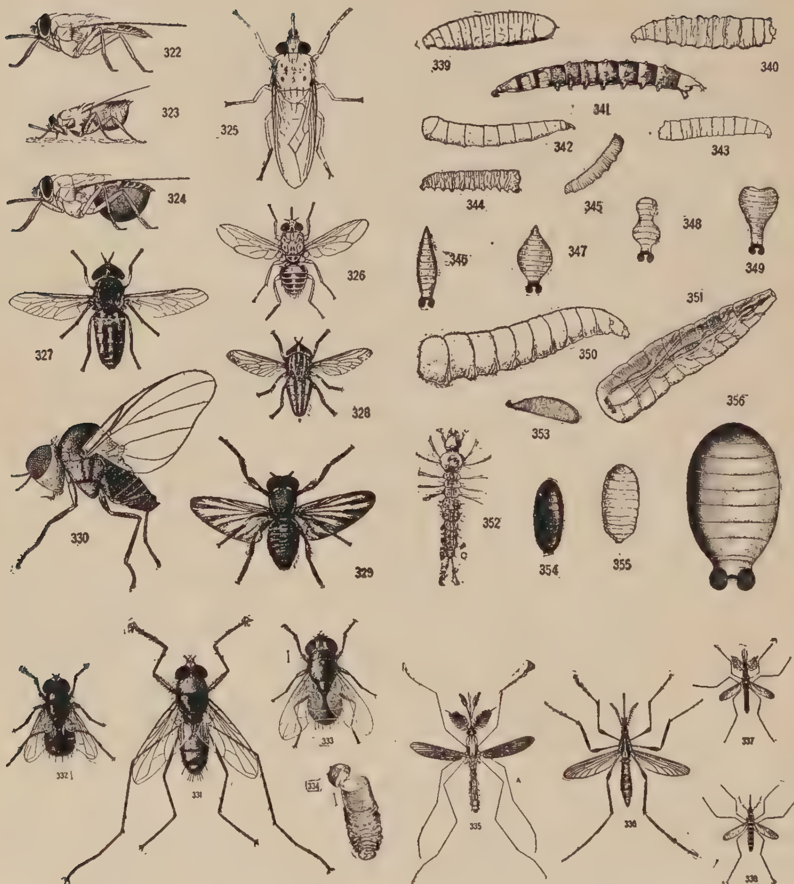
The cobras when they strike raise themselves high above the ground on the tail and hinder portion of the body, and then fall forward. They do not shoot the head out suddenly as do our rattle-snakes. As they fall forward their broad hood acts as a wind brake and delays the body so that the danger from the fall is minimized. In the frilled lizard of Australia, which runs very rapidly on its hind legs with the body more or less erect, the frills act as an air brake in the same way.

We have now considered all the flying animals that live on land; but in addition there are some that live in water.

Chief among the aquatic flying creatures are the flying-fishes which are abundant in all the warmer seas. These fishes are one of the great wonders of the oceans. Leaving the water with a tremendous rush, the large side fins, which in some kinds reach a length equal to two-thirds the total body length or even more, are rigidly extended like the wings of an aeroplane and held in this position by powerful muscles. Supported by these great fins the fish is able to go for an astonishingly long distance, and in a strong wind to rise to a considerable height. When its momentum is expended it falls back into the water, or sometimes takes a fresh start by the vigorous action of its tail, the lower and larger part of which is dipped beneath the surface.

The old question, which was created first, the hen or the egg, is replaced at sea by the equally old question, do flying-fishes really fly, or do they not? This question is always being discussed somewhere or other, and has been under continual discussion ever since man first sailed the seas. Every sailor knows that the wings of flying-fishes move, for he has seen them move and heard them hum; nothing but the fish could move them, and therefore he says that the fish does move them, and consequently flies after the manner of a bird. Others say the flying-fishes do not fly because they cannot; the muscles about the base of the wing-like fins, though large and strong, are merely used to keep the fins extended and serve no other purpose. The sailor retorts that this is pure theory and not to be considered in the light of the observed fact that the wings are actually moved. Both sides, the realists and the theorists, support their views with all sorts of arguments from the realms of marine biology, anatomy, and marine mythology, and the discussion finally comes to rest exactly where it started. No real sailor will admit that flying-fishes cannot fly, while no landsman will admit they can.

In their contentions both are partly right. It has been shown that flying-fishes fly so far that their flight cannot be explained on the basis of the original impetus alone; no one



FIGS. 322–356. Biting and parasitic Flies, and some maggots and pupae of Flies.

For explanations of the figures see pp. xxi, xxii.

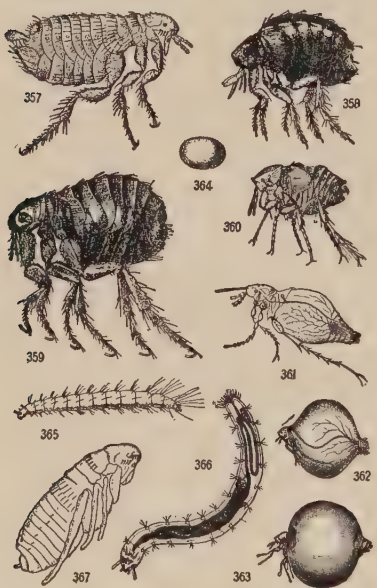
who has seen them at close quarters can doubt the movement of their fins. Therefore, while flying-fish are mainly gliders, their flight to some extent is aided by the movement of their fins.

While flying-fishes jump from the water and glide away right and left before a steamer, a small boat does not disturb them in the least. If you are out in a small boat there may be thousands of them about you and you may never learn their presence. Through this peculiarity they are easy to secure.

When the trade wind is blowing the surface of the sea is covered with little waves from which the sunlight is reflected so that a relatively small amount penetrates beneath the surface. While to us the ocean looks especially bright and sparkling in a brisk breeze, beneath the surface it is dark and gloomy, for all the myriads of sparkles that catch our eye mean a corresponding amount of light rebounding from the surface instead of penetrating. It is under these conditions that the fishermen go forth to catch the flying-fish. For this they must go for a long distance, until the shore begins to disappear, as the flying-fish is preëminently a creature of the high seas and well knows the dangers that lurk in shallow water. Having arrived at what he considers a suitable location, the fisherman throws overboard some oily matter, usually, because most available, some half decayed flying-fishes from a previous catch. The oil spreads out and forms a relatively quiet area about the boat; the waves within this cease to sparkle, and the surface here takes on a dark and gloomy aspect. But looked at from below just the reverse occurs; the stilling of the wavelets results in the formation of a brilliantly lighted patch. Though previously no flying-fish at all were visible, the water about the boat now teems with them; they have come from all directions attracted by the bright spot on the surface. With frantic haste they are scooped into the boat with dip-nets — they do not attempt to fly — until suddenly they all vanish. Immediately several large hooks on strong lines are thrown out, each with a flying-fish as bait, and one or more is often seized

by a dolphin or a shark, whatever it was that frightened the flying-fish away. The oil has now become so scattered that its effect is lost, and the fisherman sails away to try their luck elsewhere.

There are three little flying-fishes that live in fresh water, one, the most expert of them, in the rivers of western Africa,



FIGS. 357–367. Fleas.

FIGS. 368–369. The Pine Saw-fly.

For explanations of the figures see p. xxii.

and the other two, which are only able to make short flights, in eastern South America.

Flying-fishes are no new creation, for as far back as the Triassic seas there were at least three kinds, in some respects much better adapted for flight than are those of the present day.

Brief mention must be made of those so-called flying-fishes

that do not fly, chief among which are the flying gurnards. In these fishes the side fins are enormous, and often very brightly colored, and look as if they could be used in flight. But these are sluggish bottom living fishes found only in shallow water near the shores and more or less like sculpins in their habits. They never leave the water except perhaps, and very rarely, in a short clumsy jump. The bat-fishes of the tropics, which are enormous rays, like many other fishes will sometimes leap above the surface; but they do not fly.

In some parts of the ocean the passage of a steamer will frighten from the water objects which at first sight look like flying-fishes, of about the same size but thinner and more cylindrical. When these things leave the water instead of scattering as does a company of flying-fishes they always keep together in a close formation maintaining the same distance from each other, and all the members of a company always drop into the sea at the same time. I first saw these off north-western Africa and it was the close formation that attracted my attention. Their flight is rather short, and it was difficult to catch them with the telescope; but when I did I found that they were cuttle-fish or squid, flying tail first, and easily distinguishable from the fishes by their large dark eyes at the wrong end.

The only other flying thing at sea, except the birds, and sometimes bats on their migrations, is a small crustacean that lives in great numbers at the surface in some places. This creature often jumps clear of the water, and is said to prolong its leap by gliding through the air after the manner of a flying-squirrel.

THE LARGEST LIVING CREATURES

Three hundred years ago the question, what are the largest creatures in the world? was very quickly answered. In those days the largest animal on the land was well known to be the dragon, while the largest animal in the sea was equally well known to be a sort of marine dragon called a sea-serpent.

With the improvement in the implements used in fighting and in hunting game the fear of the larger creatures on the land declined and people gradually came to know them in their true proportions.

Most dragons can be traced to three sorts of huge reptiles which have been variously supplied with wings and other features by an unrestricted use of the imagination stimulated by intense fear.

In southern Europe and in northern Africa the local dragons were enormous snakes of which the people stood in mortal terror. These have now been quite extinct for many centuries. In other regions, too, as in western China, large snakes, alone or embellished with features taken from other animals, formed the basis for the local dragons.

The eastern Chinese dragon was based wholly or mainly upon the Chinese alligator which in former times was common in many Chinese rivers, though now it is confined to the lower portion of the Yang-tse where it is not common and never reaches a large size. Outside of China alligators are found only in the southern United States.

In parts of the East Indies the local dragon was in part a huge ground lizard called a monitor, much feared by the natives in some islands, and apparently in part a giant snake.

We shall not consider dragons further. It is enough to say that on analysis they all resolve themselves into these three

elements, alligators, huge snakes, and giant lizards, usually in various combinations, all of which were vastly more numerous in the past than now and all of which were greatly feared.

Huge creatures in the ocean when not recognized were commonly assumed to be related to the terrible dragons on the land and hence endowed with reptilian features and designated as sea-serpents or sea-dragons.

In the last twenty years we have heard less and less about the sea-serpent. The size of ships has rapidly increased, and steamers have gradually replaced the sailing craft. There has been no change in the creatures of the sea; but the change in our vantage point for observing them from the low and insecure wave-washed deck of a small sailing boat to the high, comfortable, secure, and relatively dry deck of a much larger steamer has removed the element of fear and hence dulled the imagination so that sailors are now able to study calmly and report correctly what they see.

Most sea-serpents when examined carefully resolve themselves into giant squid or cuttle-fish; but large sharks swimming in pairs one behind the other, whales, troops of dolphins and porpoises, and sometimes other creatures have also been described as sea-serpents.

The element of size in any creature always incites our curiosity. Mere size alone is always interesting, more especially in a creature larger than ourselves. But before we mention the giants of the animal kingdom let us state that the half way point between the largest of the land animals, the elephant, and the smallest, the most minute among the protozoans, is represented by a creature perhaps a little smaller than the blow-fly; and furthermore that all the animals we have to fear the most, our most inveterate and our deadliest enemies, are smaller than the blow-fly.

In certain groups, such as the birds, all the individuals of a given kind are of nearly the same size when fully grown, though the adult size of the two sexes differs more or less, the males being usually larger than the females, but smaller in such

birds as hawks and phalaropes. Some mammals, like the bats, show little variation, but most show more than do the birds. In the bears, the elephants, and some other types after the adult stage is reached the size keeps on increasing slowly until death so that the adults are very variable.

In the turtles, lizards, snakes and crocodiles, as in all, or nearly all, the fishes, the size keeps on increasing long after the adult stage is reached, and giant individuals occur in all those forms in which size and increasing sluggishness do not invite destruction by interfering with the capture of the prey or by diminishing the power of defense.

Some kinds of insects have a very definite adult size, like the swallow-tails among the butterflies, while in others the adult size is variable, as in our little aphid-eating butterfly. Other insects often vary very greatly in their size in different regions, while in very many the size, normally constant, may become much reduced by adverse conditions.

The African elephant is the largest of land creatures, weighing about 3 tons and reaching a height of 11 feet at the shoulders; but it is only one-tenth the size of the largest whales, or perhaps less. The Indian elephant and its relatives, which are really quite different animals, are not so large. By no means all African elephants are 11 feet in height, only the oldest males. The life of an elephant is rather long, for they have lived in captivity for as much as 130 years.

While the African elephant is the bulkiest of animals, the giraffes are much the tallest; most giraffes are 15 or 16 feet in height, but one sort reaches 18 feet. The body is short, however, only 7 feet in length exclusive of the tail.

Of the various bears much the largest are the great brown bears of the Alaskan peninsula and Kadiak Island which may run up as high as 1800 pounds in weight.

Of the cat tribe the largest is the tiger, reaching 11 feet from nose to tip of tail. The Bengal tiger is somewhat less, rarely so much as 10 feet long.

The tiger, by the way, inhabits a vast extent of territory,

ranging from the Caspian Sea and the Euphrates river to the Okhotsk Sea and Amurland and southward throughout China, India and the Malay countries to some of the islands in the Malayan archipelago. The largest tigers are those in the Amur country, where it is extremely cold in winter. I saw a skin of one shot on Sakhalin which I was told was 12 feet long.

The animal called "tigre" in Central and South America is the jaguar, while the African "tiger" is the leopard.

The lion is of about the same size as the tiger, but usually slightly less. The longest measure 10 feet 6 inches, of which the tail occupies about 3 feet. Lionesses are about 1 foot shorter than their mates.

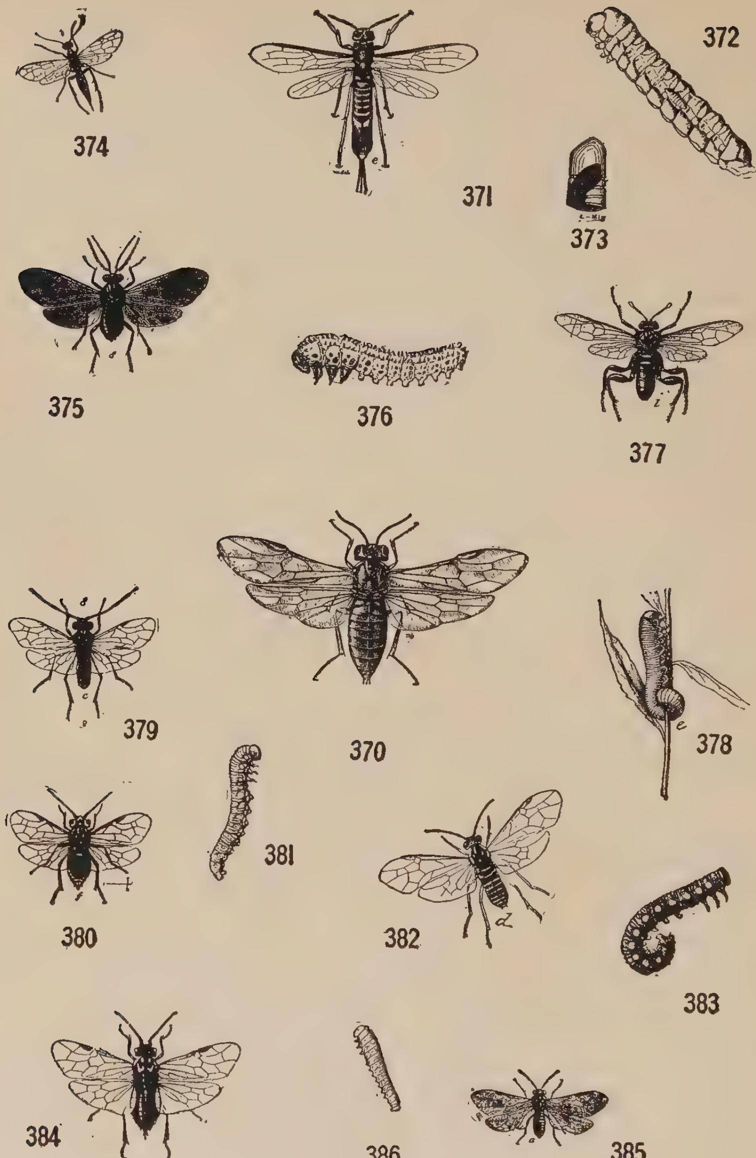
Lions occur all over Africa, excepting in the regions where they have been exterminated, and locally eastward to northwestern India. Within historic times they lived in southeastern Europe west to the river Potamo and the Pindus mountains and south to the Gulf of Corinth, as well as throughout the greater part of northern and central Hindustan.

The animal called "lion" in North and South America is the puma or cougar.

By way of contrast to these animals the smallest mammal is a little shrew known from only three captured in the District of Columbia and in Virginia, which has a body length of only 2 3/8 inches with 1 3/16 inches of tail.

The ostrich is the largest of the birds, standing as much as 8 feet high and weighing 300 pounds. The true ostriches, of several different kinds, are confined to Africa and Arabia. The American ostriches are more properly called rheas, and the Australian, emus. Both the rheas and the emus are much smaller than the African birds.

The wandering albatross of the windy southern oceans is the largest of the sea birds. Its body is but 4 feet long; the maximum extent of wing was found to be, from measurements taken on over 100 specimens, 11 feet 4 inches, not so great, therefore, as commonly recorded. All of the other kinds of albatrosses are smaller, though some not much so.



FIGS. 370–386. Vegetarian wasps.

For explanations of the figures see p. xxii.

The condor of the Andes is the bulkiest of the flying birds on land, 4 feet in length with a maximum extent of 9 feet 9 inches, according to an unpublished record given me by Dr. Wetmore. One that Darwin shot measured 8 feet 6 inches in expanse, and the bird probably never reaches quite 10 feet in spite of the numerous reports exceeding this.

The Californian condor of our own western mountains has just about the same expanse of wing as the South American condor, but it is a somewhat lighter and more slender bird.

Compare these birds with Princess Helen's hummingbird of Cuba, the smallest of the birds, 2 9/16 inches in total length, or without the bill and tail 1 1/4 inches.

It is very difficult to get accurate information on the largest reptiles, since these are rarely measured carefully, and there is much temptation to exaggeration.

There are many references to snakes, pythons and boas, of between 40 and 50 feet in length which have been killed in the Malay region, Sumatra, Borneo and the Philippines, and also in Africa. The largest pythons as we know them now are from 18 to 20, occasionally even somewhat over 30, feet in length, though such enormous snakes are very rare. But there is no reason to believe that in the past when such huge snakes were not molested they did not grow, at least sometimes, to more than 40 feet.

The maximum accurate measurement of a snake is of a South American anaconda that reached 14 meters, or nearly 47 feet, while another measured 13 meters, or over 43, so I am informed by Dr. Afranio do Amaral. These giants were from the uninhabited region north of the Matto Grosso; elsewhere in Brazil they are rarely half as large. Huge individuals have been mentioned from the Guianas; one 36 feet in length was killed in Berbice which is said now to be in the Museum at the Hague.

The bulkiest of the poisonous snakes is the diamond backed rattler of our southern states, which reaches 8 feet 8 inches — stretched skins are of course much longer. One of the cobras is of greater length, up to 16 feet, but it is very slender.

Crocodiles reach a length of about 30 feet. One of these monsters 29 feet long and 11 feet in girth was killed many years ago in the Philippines where it apparently had been a local terror for many years. Large Nile crocodiles are usually about 15 feet in length, but sometimes much larger. Sir Samuel Baker, writing in 1875, said of the crocodiles at Gondokoro on the upper Nile near the Albert Nyanza that he frequently saw them upwards of 18 feet in length, and that there can be little doubt that they sometimes exceed 20.

One of the American crocodiles, much like the crocodile of the Nile, is found in the extreme south of Florida where it reaches more than 14 feet in length and is not rarely 10 or 12. This crocodile is peculiar in living mainly in salt water marshes. It is much more active and dangerous than the alligator from which it is easily distinguished by its narrow pointed snout.

The alligator in the southern states is known to reach 18 feet in length, possibly even 20, though in these days it rarely exceeds 12.

The wicked looking gavial of the Ganges reaches a length of 17 feet. There are much larger records, up to 30 feet or more, but I suspect that these refer to crocodiles.

The largest of the lizards is a monitor from the little island of Comodo between Flores and Sumbava in the East Indies, which is known to reach 13 feet, and is said sometimes to be much larger, 23 feet or even more. The largest American lizards are the iguanas, about 5 feet long.

Of the sea turtles the largest is the leather back which is sometimes taken on the New England coast, though its home is in the tropics. This reaches a length of about 7 feet and a weight of about 900 pounds. The loggerhead, another of the sea turtles, is of about the same weight as its maximum. At the present day large individuals of both of these are very rare.

On many isolated islands far from land, like the Galapagos Islands, Aldabra, Mauritius, Bourbon and others, there live, or have lived, gigantic land tortoises. In the Galapagos Islands

these were especially abundant, inhabiting nearly all the islands and of a more or less different type on each. Ships used to call here and take aboard these tortoises for meat, in the early days sometimes as many as 700 at one time. In the early eighteen hundreds the ship's company of a frigate in one day brought down 200 tortoises to the beach. Even as late as Darwin's visit in 1835 the staple article of food among the inhabitants of Charles Island consisted of these large tortoises.

Some of these tortoises grew to an immense size. Mr. Lawson, a resident Englishman, told Darwin he had seen several so large that it required six or eight men to lift them from the ground, and that some had afforded as much as 200 pounds of meat. The old males are the largest, and are easily distinguished from the females by the longer tail.

One of the large tortoises from Aldabra on being weighed was found to reach 870 pounds; but this was not one of the largest size.

The largest of the pond or river turtles is the alligator snapper of the Mississippi which reaches 140 pounds in weight, the shell or carapace being about 3 feet long. Our common snapper is much smaller, though reaching 70 pounds or more.

The largest frog comes from the Cameroons, on the West Coast of Africa. It is a rather stout short-legged frog with the body 10 inches or more in length and the hind legs as long again, so that when stretched out the creature measures about 2 feet. There are some other frogs nearly as large.

The largest salamander is the giant salamander of eastern Asia and Japan which reaches about 5 feet. We have a very similar but much smaller one with us which is usually about 18 inches, but occasionally as much as 2 feet long.

Of the fishes in fresh water the largest is that giant sturgeon of southeastern Europe called the "huso" which reaches 24 feet in length with a weight of 2000 pounds, though at the present day individuals weighing as much as 1200 pounds are rare. This fish has been found to attain an age of between 200 and 300 years.

FIGS. 387–496. Parasitic Wasps, Ants, and Dragon-flies.
For explanations of the figures see pp. xxiii, xxiv.

Our largest fresh water fish is the alligator gar of the southern states, ranging to Mexico and Cuba, up to 10 feet and said to reach 14 feet in length.

This great sturgeon runs down into the Black Sea, while the alligator gar also occurs in salt water, though primarily a lake and river fish.

The largest fish occurring only in fresh water is the Chinese river sword fish, allied to our common spoon-billed cat, which grows to a length of 20 feet.

The European cat-fish is also very large, reaching 9 or 10 feet in length, and rarely as much as 13 feet, with a weight in the Danube of from 400 to 500 pounds, and in southern Russia of over 600 pounds.

The largest Mississippi cat-fish reaches a length of over 5 feet and a weight of 210 pounds or even more.

In contrast to these, in the smallest of fresh water fishes the males are not more than 3/4 inch in length, with the females somewhat larger.

Let us digress a bit to mention the giants of past ages. The largest living things the earth has ever seen were reptiles of the sort called dinosaurs. The longest of these reached a length of about 100 feet. An actual skeleton of one, called *Diplodocus*, in the Carnegie Museum at Pittsburgh, is 87 feet in total length and 14 1/2 feet high at the hips. The tail is 50 feet, the body 15 feet, and the neck 22 feet in length. The weight when alive is estimated to have been 15 tons or more. This creature was about as long as the longest whales today, though much less in bulk. But not all dinosaurs were large; some were no larger than a fowl.

From time to time one hears of giant reptiles, dinosaurs or similar types, which have been seen in various places. Within the past twenty years they have been reported from west Africa, Alaska and New Guinea, and aquatic ones from Argentina. These have the same significance as the dragons of the past and are the result of fright and imagination. They are based upon elephants or bears or other creatures, endowed

with features taken from the fossils. The great reptiles of the past are all extinct, on the land as well as in the sea.

Passing now to insects we find in South America the moth with the greatest spread of wing. This is the owl-moth or agrippina, with an expanse of 11 inches. The Atlas moth of

FIGS. 407–411. Four young Dragon-flies, and the adult of one of them.

For explanations of the figures see p. xxiii.

southeastern and southern Asia and the adjacent islands has much broader wings which spread 10 inches in the largest I have measured, but probably sometimes more.

Our largest moth in eastern North America is the common cecropia, reaching 7 1/2 inches in expanse; the equally common polyphemus is not much smaller, reaching 6 1/2 inches.

The broadest butterfly is *Papilio antimachus* of western Africa, from 8 to 9 inches across the wings, but its wings are

very narrow. Much broader are the wings of the dull females of the gorgeous *Ornithopteras* of the East Indies, some of which spread 8 inches.

The most vivid of all butterflies are the males of the South American *Morphos*, several of which are very large, 7 1/2 inches across the wings, equalled in size in the western hemisphere only by the related but much more sombre owl butterflies or *Caligos*.

Of the beetles the bulkiest and heaviest are the largest of the elephant beetles of South America; one which Mr. H. S. Barber measured for me was 4 5/8 inches in total length, 3 3/4 inches from end of body to tip of jaws, and 2 1/8 inches broad. A longicorn beetle from the Pacific islands, found in Fiji and other places, is the longest of the beetles, 5 7/8 inches in body length, but only 1 3/4 inches across.

FIGS. 412–414. Grasshoppers.

For explanations of the figures see pp. xxiii, xxiv.

The African goliath beetles are very large, one which I measured being 3 7/8 inches long and 1 7/8 inches across.

The well known Hercules beetle, found at Dominica and in many other places in the American tropics, reaches a length of 6 3/8 inches, but a considerable part of this is made up of the long projecting horn. From the tip of the jaws to the hinder end of the body it is only 3 1/4 inches, the width being only 1 13/16 inches.

Extremely long front legs are possessed by a curious beetle from tropical America (*Acrocinus longimanus*). One secured by Mr. Barber measures no less than 13 1/8 inches from claw to claw across these extended legs.

Contrast with these a little beetle which feeds on the spores of fungi (*Nanosella fungi*) and is less then 1/100 inch in length.

Italian fleas are commonly assumed to be the fleas *par excellence*, though some maintain the Californian product is

superior. But let me say that of all the fleas the largest known, about a quarter of an inch in length, has so far been found only in the District of Columbia or just across its borders. This flea is quite innocuous, as it lives on field mice.

With us the humble angle-worms are never very large, but in other places some kinds grow to a great size. The largest, from 4 to 6 feet long, much larger than many of the snakes, are from Tasmania.

Some sea creatures are immensely larger than any of the land creatures, as will be seen in the succeeding pages.

While size in the abstract is interesting, the larger animals of whatever group are relatively unimportant. They need abundant food, and are therefore relatively few in numbers, while being large very many enemies converge upon them, internal as well as external. A relatively slight decrease from any cause in their food supply endangers their existence; too much activity on the part of internal parasites enfeebles them and has the same effect as a reduction in the food supply. The balance between them and their environment is too delicate to admit of any alteration. If their territory is invaded by predaceous creatures able to feed upon them, as a rule they soon become extinct.

It is the smaller animals that dominate the world and with which we must compete. The elephants and most of the wild hoofed animals would long have been extinct had it not been for numerous protecting laws. For us the rabbits, rats and mice are of far more significance, while the little insect eating birds are more important than the condors or the ostriches. And further down the scale the smaller insects and the minute protozoans are far more important still.

THE BASIS OF LIFE IN THE SEA

What is the biological significance of a large whale? The immediate answer is that the largest whale, the Blue or Sulphur-bottom, is the largest animal known, living or extinct, reaching a length of 90 feet. The weight of such a monster has not been determined; but a torpedo boat of the same length with approximately the same under water contour would displace 32 tons. If we assume a weight of 30 tons for the largest whale we shall not be far out of the way.

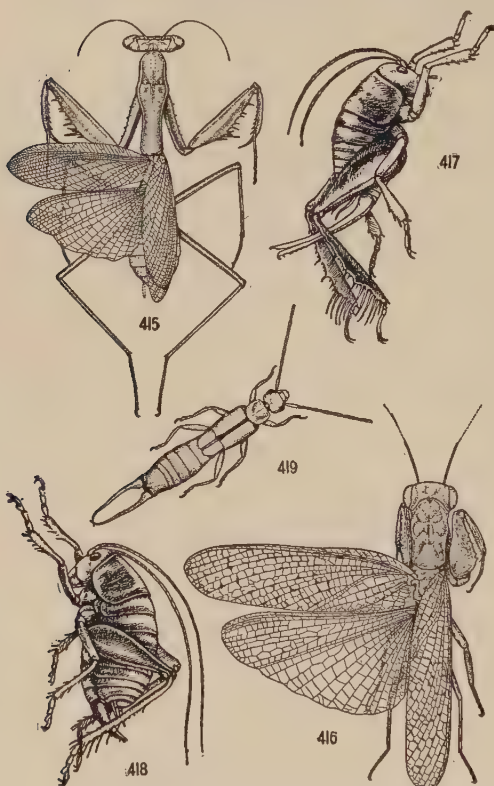
Size, of course, is only relative. I once was in a whale-boat from which a 70-foot whale had been harpooned. The creature did not make off up the wind as he should have done, but sulked and came to the surface under the boat, spilling us all into the sea. As he came up through the clear water he looked like a small island, and from the water he looked like an ocean liner as he moved away. But now another boat was fast to him and he was killed and dragged ashore, where he seemed to shrink to relatively diminutive proportions.

All whales are carnivorous; but all the fishes, cuttle-fish and smaller creatures upon which they feed are ultimately dependent upon plant life for their existence. How much vegetable material does it take to support a whale?

If the 30 tons represented by a very large whale were incorporated in the bodies of cattle, these cattle would require for their support each day the amount of fats and carbohydrates present in the hay yielded by an acre of good meadow land in a whole season's growth. A whale requires much less food than its equivalent in cows, since it is entirely supported by the water and is much less active. On the other hand, consuming only other animals, many of which themselves are two or three or more steps removed from a vegetable diet,

there is a very large wastage in the nutritive matter in the sea plants before it enters the whale. We shall assume that the latter offsets the former.

The state of Rhode Island has an area of 1,250 square miles. If this state were wholly planted in grass and yielded as much hay per acre as the average meadow, enough food would be produced in the course of a summer to support a maximum of about 2,150 of these great whales for a year; the District of Columbia could support less than 125.



FIGS. 415–419. Mantises, Crickets, and an Earwig.

For explanations of the figures see p. xxiv.

Yet whales are abundant in certain regions. I have myself seen on the Pacific more than a hundred at one time, though these were of a kind much smaller than the Blue whale. At the height of the whale fishery at Spitzbergen the catch averaged slightly over a thousand whales a year, all large ones. The food of those that were killed, not considering those left alive, would represent the grass crop from an area eight times the size of the District of Columbia.

These rough calculations are sufficient to show that the pastures of the sea must be very rich, for not only do the marine pastures support numerous whales of all sizes, but in addition various large sharks, a number over 40 and one over 50, and said to reach 70, feet in length, and other huge fishes which are not eaten by whales and therefore compete with them for the food supply. And then there are the seals and the sea-birds and hosts of bottom living animals in many places forming living carpets for miles and miles, all browsing, so to speak, directly, or mostly indirectly, on the same pastures.

It has been said that the marine pastures are richer than the pastures of the land, and on occasion this certainly seems true; but close comparison between the two is difficult. In the first place sea animals require much less nutriment than those on land so that comparison bulk for bulk between the two means little. Furthermore many whales and many of the larger fishes, like the mackerel and the herring, are migratory creatures, wandering regularly or more or less irregularly from place to place. On land the growth of vegetation with us ceases in the winter, and in the tropics is much reduced in the dry season; nowhere is it uniform throughout the year. In the sea the growth of vegetation also varies at different times or seasons quite as much as on the land.

On land all vegetation grows on the ground, or on some support fixed to the ground, and all animals live on or in the ground or among the plants growing upon it. Such animals as traverse the air do so only as a means of getting from place to place or, a very few, to feed upon others so engaged. The air, for all practical purposes, is a sterile medium. Potentially, however, conditions are quite otherwise.

In the city of Caracas I was always greatly interested by the sight of festoons of plants, especially "wild pine-apples" or bromelias, growing on the electric light cables high in air and nourished only by substances extracted from the air. What does this signify? It proclaims the fact that wherever a plant can find support it can grow in the air just as well as on the

ground, and suggests that if plants could only hover in the air like humming-birds the atmosphere in the warmer regions would soon be converted into a dense jungle. Such a calamity is averted by the great weight of plant tissues as compared to air which forces all plants to grow attached directly or indirectly to the ground.

Now water is 814 times as heavy as air, almost as heavy as protoplasm, the living substance of which both animals and plants are composed. Only the very slightest modifications are necessary to enable plants and animals to float about suspended at any depth in sea water like the particles of mud in a muddy river.

The only plants we see in the ocean are along the shores attached to the rocks like the devil's aprons or laminarias, the rock-weeds, the sea-lettuces, etc., or rooted in the mud like the eel-grass. The gulf-weed or sargassum, so frequently seen floating in large patches on the north Atlantic, is in reality a rock-weed from the Caribbean region growing feebly but never fruiting, and finally dying and going to the bottom, exactly as so many willow twigs would do floating on the surface of a lake.

Quite a number of creatures browse upon these plants along the shores, the largest of these being the manatees, when in the sea, the sea-cows and the dugongs; but it is obvious that the narrow fringe of sea-weeds along the coasts cannot supply the food of all the creatures upon which the whales subsist, much less the basic food of the myriads and myriads of other creatures with which the open ocean is populated. It is true that some of the brown sea-weeds are very abundant, like the kelps on our New England and our western coasts, and some are of very considerable size, reaching 300, 400 or even 700 feet in length; but their actual mass when considered in relation to the food requirements of the sea animals is almost infinitesimal.

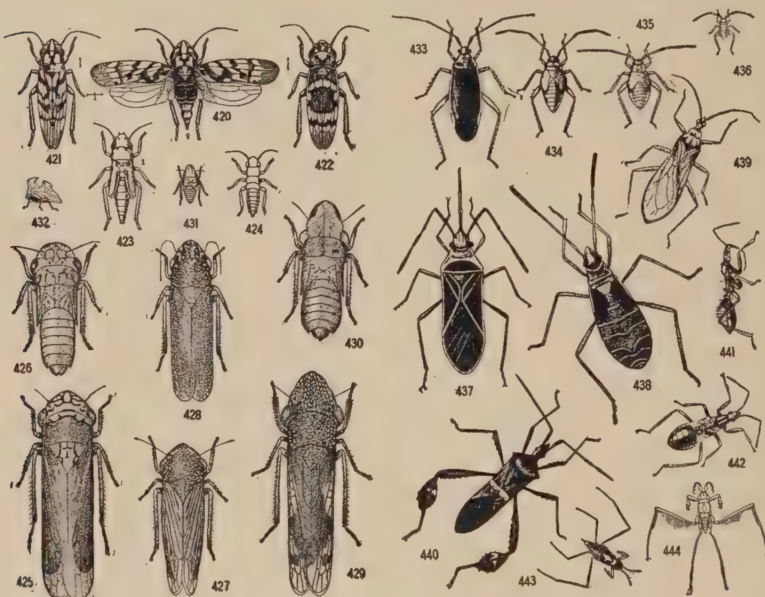
On pools and ponds and in quiet backwaters from lakes and rivers in the summer time the water is often quite hidden from

view by the little floating plants called duck-weeds or lemnas. Why do we never find floating sea-weeds living in the same way? On a pond or lake if the duck-weeds are blown about by the winds it does not much matter where they go; the conditions are about the same everywhere and some at least will eventually be washed into a backwater like the one from which they came. In the sea a floating plant if not washed up on some beach would sooner or later be carried to a region with a different temperature or with different chemical conditions where it would eventually die, just as the sargassum does. Large free floating plants requiring a large amount of nutritive matter and of sunlight and a more or less constant temperature, at least for considerable periods each year, such as are often so abundant in fresh waters, cannot exist in the sea because of the certainty of eventual destruction through the impossibility of remaining continually within the narrow range of conditions under which alone their existence can be maintained.

But suppose the bulk of a 400 foot sea-weed were distributed among several billions of microscopic plants. These would soon separate in all directions; some would sink to all depths below the surface, and those at the surface would be widely scattered by the winds and waves. Millions might be swept away and lost, but other millions would always be present constantly bringing forth millions of young. If small enough and distributed from the surface of the sea down to the limit of effective light penetration, about 650 feet as a maximum, and capable of rapid reproduction, such plants would be unloseable, so to speak, and always permanently present in any given locality.

This is exactly what occurs in the ocean. The great bulk of marine vegetation we cannot see. It is composed mainly of plants called diatoms, especially prolific in cold regions and at cold seasons, of peridinians in the tropics and at warm seasons, of the exceedingly small coccolithophorids, the very minute flagellates, and of other types.

The numbers of these little plants can only be imagined, not really appreciated. It has been calculated that in the water of Kiel Bay there are 6,336,000 diatoms alone per quart. If there are 6,336,000 diatoms in a quart of water, how many would there be in an area of the ocean the size of the state



FIGS. 420–444. Leaf-hoppers, and various true bugs.

For explanations of the figures see p. xxiv.

of Rhode Island, that is 1,250 square miles, down to a depth of 650 feet, the depth to which at least they may be assumed to live?

Of course many regions are much poorer in diatoms than Kiel Bay, while many are richer; in the Arctic and in the Antarctic they may be so abundant at times as to color the water for miles and to give it a slight, but noticeable, "smooth" feeling.

The preceding paragraphs would seem to imply a static condition in the oceanic flora, which is quite the reverse of the real condition. The calculation given for Kiel Bay is for a single season only. In a given spot at times the sea may swarm with microscopic plants, while at other times it may be practically barren. In some places the difference in productivity at different seasons is almost as great as the difference in the productivity of your garden between mid-summer and mid-winter. Usually the difference at different times is less than this, but the amount of plant life present in any given region of the sea is always very variable.

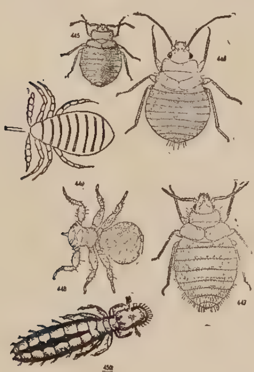
What are the diatoms? The diatoms are very minute plants which occur wherever there is moisture and light, in fresh, brackish and salt water, on the moist surfaces of rocks, etc. The fresh water forms all differ from those in the sea or in brackish water. Many kinds live attached, but many float about suspended in the water, often in incredible numbers. The attached forms usually form a brownish stratum or a furry covering over plants and other objects in the water. In the Arctic the beginning of spring is foreshadowed by the brownish discoloration of the under surface of the ice due to a scum of bottom living diatoms which have risen up and become attached to it.

The body of the diatom is enclosed within two lids or valves which fit together somewhat like the bottom and cover of a pill-box. These are fashioned of silica, and are of the most exquisite beauty, often highly ornamented, and of various shapes, oval, crescentic, S-shaped, linear, or wedge-shaped, though most of them are naviculoid or canoe-shaped. But most of the important marine types form chains. Of a medium sized species it would take 200 individuals in a row to make an inch; while a few are larger than this, many are much smaller.

Diatoms reproduce mainly by simple division into two, each one which divides into two, making four, and so on. The capabilities of this process may be appreciated when it is realized that if one diatom should divide into two in twenty-four hours,

and its progeny do the same, in the course of a single month a thousand millions would be produced.

So far as I am aware the rapidity of multiplication of the marine diatoms under optimum conditions has never been satisfactorily determined. But it has been calculated that a single diatom will give rise to a thousand millions in a month. With 6,000,000 diatoms, more or less, to a quart of water in such a locality as Kiel Bay, each one with a reproductive capacity of roughly 1,000,000,000 per month, all of the diatoms could be destroyed except for a single one to each 166 quarts of water, yet in a month the full number would be again restored. This shows clearly the immense advantage the minute diatoms have over larger plants as floating organisms in the sea, and why it is that the marine vegetation except along the shores is all microscopic, and not only microscopic but extremely small.



FIGS. 445–450. Parasitic insects.

For explanations of the figures see pp. xxiv, xxv.

The peridinians, coccolithophorids, flagellates, etc., while very different from the diatoms in bodily form and structure, are more or less similar in their relations to the marine world, so that it will not be necessary to consider them in detail.

While these little plants are able to increase at a most amazing speed and at times occur in incredible abundance, this only takes place under a small range of conditions, occurring for the most part at certain limited seasons. On land in many regions when the drought is broken by the rains grasses and many other plants immediately appear in great abundance. Each grass blade is the equivalent in dry nutritive material of many million diatoms, and the synthesis or formation of nutritive material under these conditions is probably at least as rapid as it ever is at sea.

We live on land and are accustomed to strike an annual average of the conditions on our farms. The study of the sea is in its infancy and we know it mostly from investigations in the spring and summer months. Until we know our seas throughout the year in detail we cannot compare their potential productivity with that of our land areas.

These floating very small sea plants occur in all localities, but they are naturally much more abundant in some places than in others. They are subject to great seasonal fluctuations in their numbers, and they become less common, many of them entirely disappearing, toward mid-ocean.

They are so very small that, although their presence may convert the sea water into a thin living-vegetable soup, special adaptations are necessary to enable animals to feed upon them.

These adaptations are along three main lines.

Many animals of a structure very similar to that of these plants, some almost as small but others larger, live among them entangling them in net-works of slender sticky threads projected from their bodies. Such are the oceanic foraminifera and the radiolarians. Some of the peridinians, too, are incapable of synthesizing inorganic into organic substances, and therefore live upon the other little floating plants in the same way that rusts and blights live upon the leaves of plants on land.

Some animal types have given rise to very small forms which are able to pick out the little clusters of minute plants from the sea water. It is rather curious that the two animal groups to which, outside of the vertebrates, all the giants of the sea belong, the crustaceans and the molluscs, should have been the ones to produce the vast bulk of small creatures which feed upon the little plants.

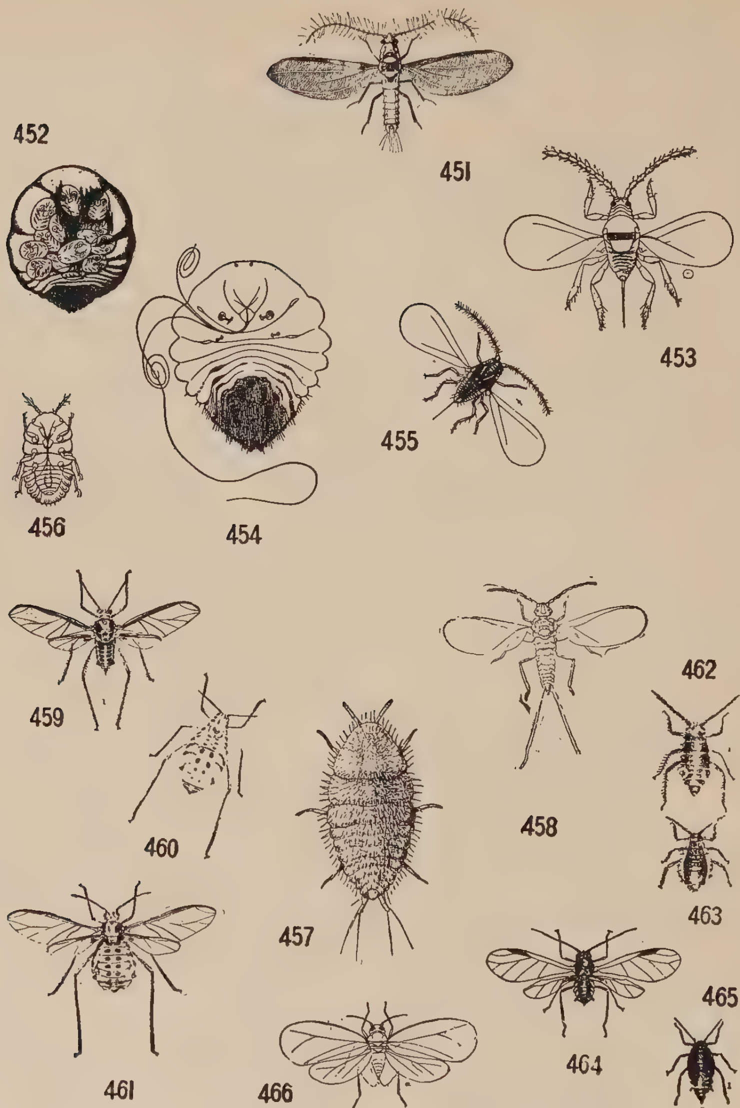
Most numerous in kinds and numbers are the very small crustaceans of many different sorts which at certain places and at certain seasons occur in myriads and are present in greater or lesser abundance almost everywhere, and the very young stages of many of the larger ones — crabs, lobsters, shrimps, etc. Just as on land the insects are the chief intermediates

through whose services plant substance is made available for spiders, scorpions, predaceous insects, and most vertebrates that are not plant feeders, so their close relatives the crustaceans are the main factors in the conversion of the microscopic plants in the ocean into a form in which their substance can be used by other invertebrates and by fish and whales.

Of these little crustaceans, the copepods are the most important, occurring in very great variety and in enormous numbers. Sometimes they are so very abundant as to give a pinkish or a red color to the sea for many miles, when they become important as a food for certain whale-bone whales. The euphausians also, small delicate shrimp-like creatures showing little variety, also feed upon these small plants, and may be as abundant, in bulk, though not in numbers, as the copepods. One of these, which in the spring time swarms in the fjords of northwestern Europe, then forms the exclusive food of the giant Blue whale in that region. The common rorqual, closely related to this monster and reaching a length of 70 feet, feeds partly on fish and is frequently seen feasting among shoals of herring which themselves are feeding upon the copepods and other small crustaceans which consume the plants.

Before leaving the copepods it should be mentioned that of all sea creatures they have shown themselves the most versatile in making use of reserves of food material. Besides the free swimming ones, and the more numerous kinds of bottom living ones, there are many that live in the food-collecting apparatus of the sea-squirts stealing the food gathered by them, in the digestive canal of crinoids, and in similar situations, while others, become parasitic, and often very large, as "fish-lice," prey upon the very creatures which, directly or indirectly, are feeding upon their plant-eating relatives, just as the bird bot-flies live on the blood of insect-eating birds. One of these, in fresh water, lives upon the gums of the crocodile, which is relieved of its unwelcome presence through the attentions of the crocodile bird.

Besides the very small crustaceans the chief plant eaters of



FIGS. 451–466. Scale insects, Aphids, and Mealy-wings.

For explanations of the figures see p. xxv.

the open ocean are curious and delicate little molluscs, the "sea butterflies" or pteropods and their allies. But while some forms of these eat plants, most of them live upon minute plant eating animals, mostly small crustaceans and other molluscs. There are, as compared with the crustaceans, relatively few kinds; but some of them occur in incredible numbers, and in the seas about Greenland and in other places they form an important part of the food of the whale-bone whales. So abundant are some of the shell bearing species that in various parts of the Gulf of Mexico, the Mediterranean, the Bay of Biscay and elsewhere the sea bottom is more or less exclusively composed of their dead remains, just as in other places it is almost entirely composed of the shells of the foraminifera or the frustules of diatoms.

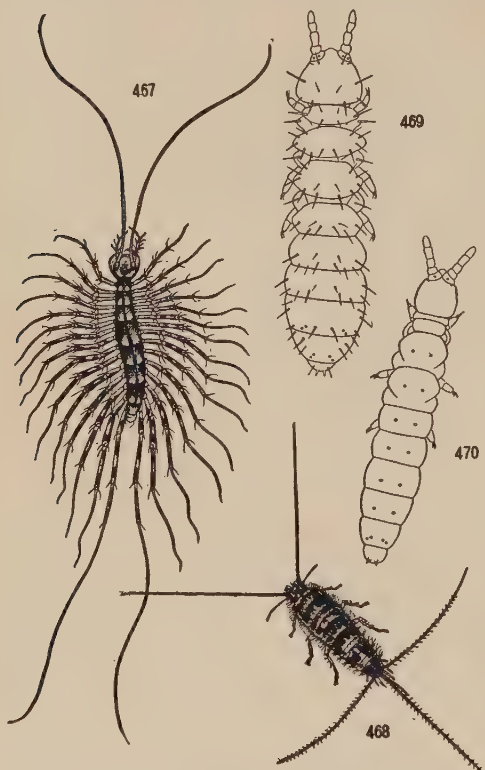
The third method of devouring the minute oceanic plants is by filtering the water and thus concentrating them. The only oceanic animals that have recourse to this process are the salps and the appendicularians, queer creatures allied to the sea-squirts, and certain of the smaller fishes, like the menhaden. Their straining apparatus is most wonderfully efficient, and it is surprising to learn, from looking at the contents of their stomachs through a microscope how small is the size of some of the organisms they capture.

In the bodies of the small crustaceans, the pteropods and other allied molluscs, the salps and their relatives, the foraminifera and a few other types, the nutritive matter represented by the microscopic plants is reassembled into units of appreciable size. Upon these units, for the most part upon the crustaceans which represent the most abundant and most generally distributed of these units, feed all the other creatures of the open ocean, directly or indirectly.

Consuming these directly are larger crustaceans and molluscs, numerous fishes, the herring and herring-like fishes, flying-fishes, the young of all, or nearly all, other marine fishes, etc., the larger salps, the jointed or annelidan worms, the nemerteans, the arrow-worms or chaetognaths, the whale-bone whales,

the smaller jelly-fishes, the ctenophores, and the very few pelagic echinoderms.

Upon these larger animals, but especially upon the fishes, live very large and formidable jelly-fishes, many kinds of fishes ranging in size up to the basking, whale and other giant sharks reaching a length of from 40 to 70 feet, the smaller members of the whale tribe, the porpoises, dolphins, etc., and the squids and cuttlefish, some of which are very large, one reaching a length of 55 feet. The squids and cuttles form almost the entire food of the great sperm whale, the bottle-nose, and the other toothed whales.



FIGS. 467–470. The House Centipede, the Fire-brat, and two Collembolans.

For explanations of the figures see p. xxv.

The fishes are the most omnivorous of all sea creatures, some kind or other eating every sort of oceanic creature and every other product of the sea.

Jelly-fishes are sometimes of enormous size, ranking with the largest of sea animals. At Nahant, Massachusetts, Professor Louis Agassiz measured one in which the bell was seven and a half feet across and the tentacles more than 120 feet in

length; this was one of those reddish ones frequently seen on the New England coast in the late summer.

On and above the surface of the sea, especially in the cooler regions where life is most abundant, live great numbers of birds which are truly oceanic and never visit land except to nest. These are mostly of the tube-nosed tribe, albatrosses, shearwaters, petrels, diving petrels, etc., and some at least are familiar to everyone who has ever been anywhere at sea. Where ocean life is especially abundant there are multitudes of auks, puffins, murres, etc., in the northern regions, and of penguins in the southern. Some terns are almost pelagic in habit, like the noddy and the black-backed, and I have seen tropic-birds hundreds of miles from land both in the Atlantic and in the Pacific.

These birds feed chiefly upon small crustaceans, since these are offered most abundantly. The albatrosses, however, eat mostly squid which they catch at night, and the other larger birds eat squid and fish when they can get them, especially the terns and tropic birds. But nearly all of these birds will eat any sea animal of suitable size or if divided into fragments of suitable size, and the floating carcass of a giant squid or whale affords a feast for thousands of them.

The only oceanic insect is a little water strider related to the water striders of our ponds which picks the small crustaceans from the sea and sucks their juices. Though small and inconspicuous they are not rare, and I have collected many of them both in the China Sea and in the Caribbean.

But as yet the story of pelagic life is only half complete. The crustaceans for the most part are the intermediates through which the organic material synthesized by the minute plants is made available for the use of the oceanic animals.

Each of the larger oceanic animals represents in itself an important reservoir of food for other animals. Besides the predaceous types there are many creatures, especially crustaceans, that live within the stomachs of other animals eating the food they swallow and within the filter of the salps con-

suming the minute organisms they are concentrating for themselves. And in addition there are bizarre, misshapen forms of very numerous sorts which live within the bodies of practically all the larger crustaceans, feasting on their juices with sometimes others living in the same way within them; while many, equally uncanny and deformed, live like lice sucking the blood of fishes, and others bore deep into the skin of whales.

Within the digestive tube of the fishes, whales and sea-birds live certain creatures not found elsewhere, except that some have been found to exist as larvae within the bodies of crustaceans. These are the tapeworms, echinorhynchs, etc., which have no stomachs but absorb through their skin the nutritive fluids in the alimentary canals of their hosts.

In the middle of the day in the tropics and in the height of the summer in the temperate regions most animals seek the shade and become more or less inactive; animal life is most in evidence early in the morning and again toward evening. At sea most animals, especially in low latitudes and where the sea is clear, seek the shade in just the same way, retreating far below the surface to the twilight zone in the daytime, reappearing at or soon after dark.

Midway between Bermuda and St. Kitts I have watched the sea for hour after hour without detecting a single living thing. But on one trip we stopped to pick up a buoy that had broken away from its moorings off New Orleans some years previously. Scarcely had the speed begun to slacken before all sorts of creatures began to appear in the shadow of the ship. A small light speck deep down slowly increased in size and was finally revealed as a fifteen foot shark, which insisted, in spite of all discouragement on the part of the sailors, in accompanying the small boat sent out to attach a line to the buoy. Other smaller sharks appeared, together with the inevitable pilot fish, and a troop of those magnificently colored fish called by sailors dolphins, though in no way like true dolphins, which are small fish-eating whales. When the buoy was

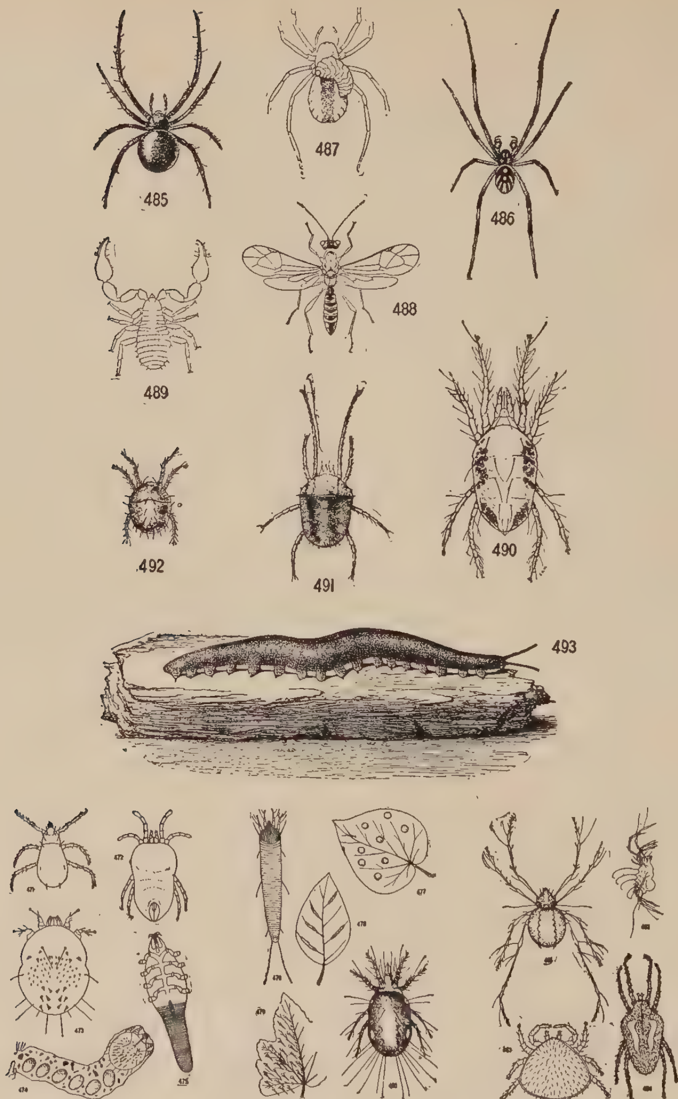
brought up to the ship the underside was seen to be festooned with growths about which played many little fishes, and on being hoisted on board many kinds of animals were found among the "weeds." Almost as soon as the steamer got under way again everything vanished, and the sea became as deserted as before. But about a score of small sharks and as many pilot fish lay on the fore deck, evidence of the prowess of some of the Chinese women in the steerage.

On the Pacific in low latitudes we found that we were most successful in finding oceanic life in the daytime if we lowered our tow-nets to about 600 feet beneath the surface. In this region there is twilight even on the brightest day at noon, and it is at these or somewhat lesser depths that the sea animals for the most part seek refuge from the light.

The animals taken in a haul 600 feet or more below the surface in the daytime and in another haul in the same place taken on the surface at 9 or 10 o'clock at night are not quite alike. Most of them are the same, but in the deeper haul there are to be found various large shrimp-like crustaceans mostly bright red in color, strange jelly-fishes of a deep red, and different sorts of sooty black fishes, some armed with enormous teeth and most ferocious in appearance, others long and eel-like with snipe-like jaws, and others looking more like ordinary fishes but with rows of brilliant phosphorescent lights along their sides; quite commonly there are also little distorted silvery fishes, also with lights, and sometimes little black sharks from 6 or 8 inches to a foot in length.

These creatures are representatives of the deep oceanic fauna which remains below the illuminated upper layers of the sea, feeding upon the surface animals when these descend in the daytime to escape the sunlight, and upon the smaller animals about them.

The oceanic plants can descend only to a maximum depth of about 650 feet in the most transparent water; but the animals which feed upon them form the food of other animals which live deeper, in perpetual shade, and these again furnish



FIGS. 471–493. Spiders, Mites, and an Onychophore.

For explanations of the figures see pp. xxv, xxvi.

food for other, though fewer, animals which live still further down, in perpetual night. The oceanic animals, largest as well as smallest at the surface, extend downward for an indefinite distance becoming less and less varied and gradually scarcer and more uniform in size; probably, indeed, no level of the sea is entirely without them.

As food becomes scarcer with increasing depth the free-swimming animals necessarily approach a general average in size. The more widely scattered the food units the greater the powers of locomotion necessary to collect an adequate supply. Very small types thus are gradually eliminated. At the same time increasing distance between food units renders it increasingly difficult to gather these in quantities sufficient to maintain a large sized animal. So with the small creatures the larger also disappear.

Well out of sight, but probably in the twilight zone where food is most abundant, thanks to the concentration due to the descent each day of animals from the sun-lit layers above, and where conditions are practically the same in all the oceans except in the extreme north and south, live giant squids and cuttles of several kinds, the largest, occasionally found floating in a dying or dead condition in the autumn on the fishing banks and sometimes in other parts of the sea, reaching a total length of at least 55 feet with the body 20 feet long and 12 feet in circumference and the eye opening 7 by 9 inches; in one individual measured the tentacular arms were 37 feet in length. In October, 1875, between twenty-five and thirty of these giant squid were found by the vessels of the Gloucester fishing fleet on the Grand Banks and cut up and used for bait. The schooner *Howard*, Capt. J. W. Collins, alone secured five of these, which were mostly from 10 to 15 feet in length, not including the arms. The schooner *Tragabigzanda*, Capt. Mallory, secured three from 8 to 12 feet long in one afternoon. Probably as many were found by the ships from other towns as by those from Gloucester.

The famous sea-serpent can from most accounts be identi-

fied as one of these great squid in a dying condition, somewhat distorted by an active imagination. The head with the frilled neck so commonly described is the tail of the squid lifted above the water. The long slender snake-like sea-serpents are the writhing arms of which the expanded ends look something like a head. Another common sea-serpent on the New England coast is a composite picture of two basking sharks which, swimming one behind the other, sometimes appear as a single creature nearly a hundred feet in length.

Other inhabitants of the twilight zone are strange fishes, especially the ribbon-fishes which may reach a length of over 20 feet with a height of a foot or less and a thickness of only an inch or two at the broadest part. Ribbon-fishes and their close relatives the oar-fishes are found floating dead or washed up on the beaches in all parts of the world, and seem not to vary from one locality to another. Very young ones, queer looking things, are sometimes taken in tow-nets.

THE SEA SHORES

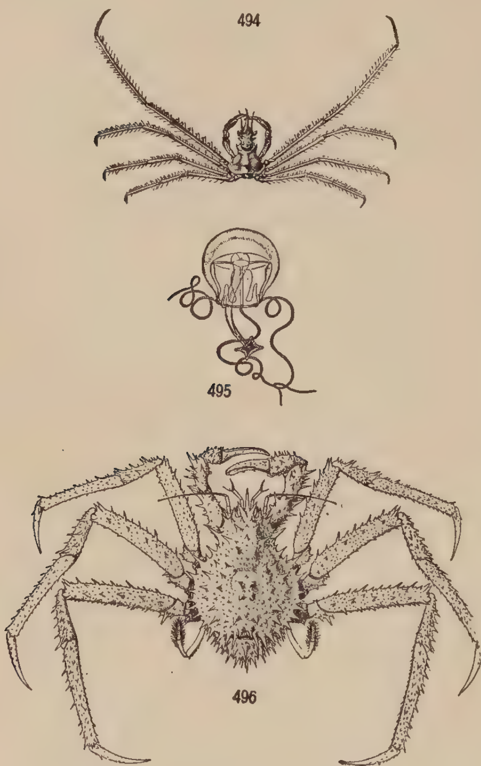
The shores of the sea are bathed by the water from the open ocean, charged with microscopic plants and small crustaceans, and with such of the creatures feeding on these as are able to support the light of day. But because of the fact that the rocks and stones and mud, and to a lesser degree the sand, offer facilities for attachment, conditions here are entirely different from what they are in the open sea.

Along the shores an attached plant, as a result of the movement of the water about it, has constantly delivered to it a fresh supply of the dissolved substances necessary for its growth, and it is maintained permanently under conditions most suitable for its existence. Hence the enormous development of the brown, green and red algae, or "sea-weeds." Some of the flowering plants, too, have become adapted to marine conditions, and one of these, the eel-grass, belonging to the pond-weed family, forms extensive beds in suitable localities.

These plants are important in providing hade and hiding places for the animals found among them, and when alive they are eaten by a few molluscs, like the periwinkle, by a few crustaceans and fish, mostly under stress of hunger, by some sea-urchins and, where these occur, by sea-cows, manatees and dugongs, by some turtles, and by a single lizard. When they die their leaves or fronds break up and the fragments form the vegetable detritus so very important as the basic food of the marine animals along the shores.

In the open sea the animals can avoid the dangers attending too violent wave action by simply descending to the quiet depths. Along the shores there is no escape from the constant movement of the water. This incessant turmoil on the shore

line, however, is easily translated from a menace into a distinct advantage; animals simply attach themselves firmly to seaweeds, stones, or other objects, and let the water do the work of bringing food to them.



FIGS. 494-496. Two deep-sea crabs and a Jelly-fish.

For explanations of the figures see p. xxvi.

On land the most successful plants are the flowering plants which grow by forming a series of units one above the other called phytons, by the multiplication of these units producing a rosette of leaves or a tall or branching leafy stem and thus exposing the maximum green surface to the sunlight and the air.

The sea water being charged with nutrient particles throughout, it is obvious that in the shallow regions any animals which are able to attach themselves and to produce in the same way as do the flowering plants an indefinite series of reduplicated units each more or less perfect in itself would be able to avail themselves to best advantage of the food materials drifting here and there and all around about them.

Attached animals, particularly animals that grow and look

like plants, are especially characteristic of the sea shores. The so-called colonial animals along the coasts which, plant-like in their growth though in no other way, live firmly fastened and secure their food from the restless water as it washes back and forth, are the sponges, certain coelenterates, including the hydroids, the corals, the sea-fans or gorgonians, the millepores, the sea-pens or pennatulids, the umbellularians, the alcyonarians, the antipatharians, the colonial anemones, and some other types, the polyzoans, the phoronids, the rhabdopleurids, the cephalodiscids, and the colonial tunicates or sea-squirts.

The sponges, all of which when alive possess a strong odor disagreeable to us, though it may be attractive to the little things on which they live, have the general mass (it can scarcely be called a body) pierced by numberless small holes leading into small tubes lined with extremely delicate hair-like structures called cilia beating inward. These small tubes lead into larger ones and these finally into an opening leading to the exterior through which a constant stream of water impelled by the constant action of the cilia in the small tubes pours outward. On its journey through the canals of the sponge this water has lost a considerable portion of the nutritive particles which originally it contained. One does not think of muscular power in connection with the apparently motionless sponges. Yet on the reefs at Bermuda at low tide I have frequently seen the calm surface of the sea much agitated by a stream of water coming from below which investigation showed originated from the outlet of a large sponge. This food collecting system of the sponges is very efficient, and other animals take advantage of it. Jointed worms of many kinds, one a much branched creature with a head on the end of every branch, live within the canals, as do various small crustaceans and brittle-stars. Barnacles, embedded in the outer layers, and some crustaceans with similar boring habits, as well as comatulids attached to the surface, all take advantage of the indraught of water into the small canals.

The polyzoans, phoronids, rhabdopleurids and cephalodiscids

FIGS. 497–520. Various Crustaceans.

For explanations of the figures see pp. xxvi, xxvii.

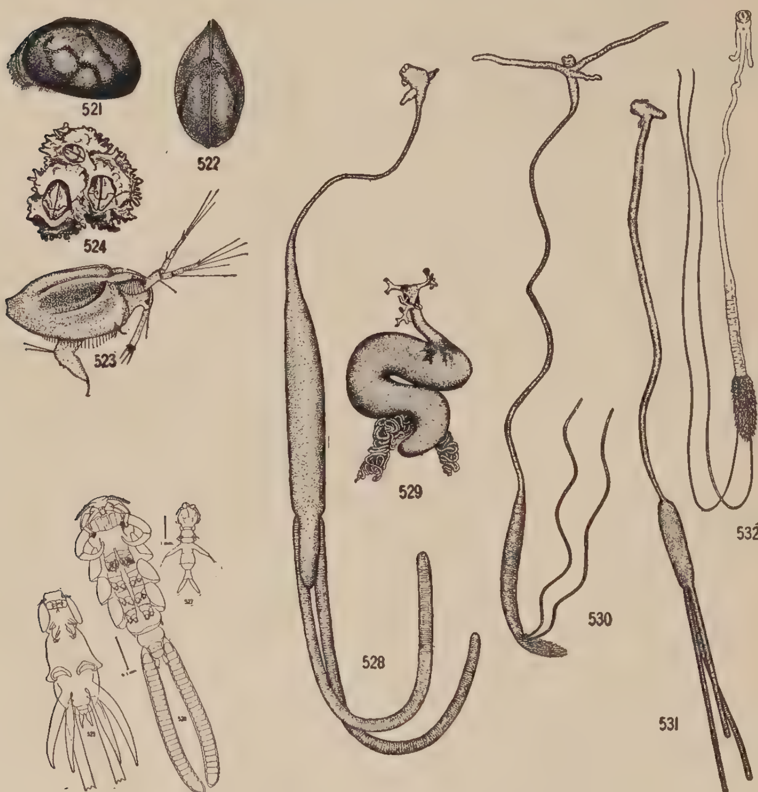
all are provided with a tentacular apparatus, the tentacles being abundantly supplied with cilia which pick the food particles from the water and pass them downward along their inner side toward the mouth. The polyzoans, common everywhere, are leaf-like or encrusting growths on sea-weeds, etc.; the individual animals in the colonies are minute but very numerous, and are often divided into various types each suited to perform a special function. A few polyzoans are solitary or occur in small colonies. The representatives of the other three groups mentioned above are mostly uncommon, local, or inhabiting rather deep water. In the phoronids and cephalodiscids the individual animals in the colony, though they all arise by budding from the same original individual and all live together in the same mass of tubes, are not connected with each other as in the polyzoans and rhabdopleurids.

The colonial tunicates or sea-squirts form thick incrustations on a usually rocky base. They are provided with an exceedingly fine sieve through which they draw the water, separating out from it the food particles.

The colonial coelenterates are very diverse in size and shape. The most familiar are the corals, millepores, red corals, and sea-fans or gorgonians of the warmer seas, and on our coasts numerous kinds of hydroids forming mossy or feathery plumes on sea-weeds or on other objects. One of the last, dried, stained green, and placed in a flower-pot, is the common "Japanese air-plant" sometimes seen offered for sale. Other sorts of coelenterates are the sea-pens and sea-feathers, deadmen's fingers and other alcyonarians, horny corals or antipatharians, and the colonial anemones. All of the sea-anemones and jelly-fishes belong to this group, and indeed many of the smaller of the latter are nothing more than the sexual units which have been liberated from hydroids.

The stony corals are important in assisting to a greater or lesser extent in the formation of the immense coral reefs which are such a conspicuous feature in many parts of the tropical seas. Some of them grow to a huge size, though the living

portion consists only of a relatively thin superficial layer. The stony axis of the red coral is familiar to all because of its use in jewelry. Some coelenterates reach a very large size, cer-



FIGS. 521–532. Curious Crustaceans.

For explanations of the figures see pp. xxvii, xxviii.

tain gorgonians attaining a height of 15 feet, and some sea-pens being 6 or 7 feet or more in length.

The colonial coelenterates consist of a great number of sac-like units which have about the opening a row of 6 or 8 or

more tentacles armed with formidable stinging organs, or of such units intermixed with other types modified from them, borne upon a flattened, wand-like, or tree-like support. The units vary from very small, in the hydroids and millepores, to an inch or so in diameter; in the non-colonial forms they may be more than a foot across. The stinging organs, which paralyze as well as sting the prey, enable the coelenterates to use as food much larger and stronger creatures than do any other of the animals which feed in this way, and they are wholly carnivorous. The coelenterates support many parasites, especially crustaceans which live within their bodies or travel up and down their stems appropriating the food which they have collected, and brittle-stars especially adapted for clinging to them, while many animals attach themselves to them which are known to live nowhere else yet which do not feed upon them, like certain anemones. Many small fishes and other creatures live among their branches, protected from their enemies by their stinging tentacles, while a wealth of different types, especially worms and molluscs, hide themselves away in the stony bases of the large corals.

A group of colonial coelenterates, the so-called siphonophores, including the Portuguese man-of-war, one of the most formidable of all the jelly-fishes on account of its unusually developed stinging powers, and a group of colonial tunicates have adopted an oceanic life and all the species drift about as true elements of the oceanic fauna.

Besides these colonial attached animals there are many others which live attached, but never form colonies, though many are highly social.

The most familiar of these are, perhaps, the barnacles, some of which, like acorn barnacles, live closely appressed to rocks, piles, the carapaces of sea-turtles, etc., while others, like the goose barnacles, formerly supposed to be the young of the barnacle goose, are stalked and are most frequently seen on floating bits of wood and on the bottom of ships. The barnacles have several pairs of curved feathery appendages with

which they sweep small animals from the sea water. These feather-like structures, together with the color, which resembles that of a barnacle goose, taken in connection with the fact that this goose was not known ever to lay eggs — its nests have only recently been discovered, in for a goose most unlikely places — gave rise to the idea of the connection between the two. The barnacles are crustaceans, related to the copepods. In their young stages they are quite like other young crustaceans, but they undergo profound changes during growth. Some barnacles, which live on whales, bore deep into their skin to attain a better anchorage. Others bury themselves in the outer layer of sponges. Many others, become parasitic, when young bore into crabs and other larger crustaceans and, losing all semblance to others of their kind, develop a mass of roots through which, plant-like, they absorb the juices of their host.

The sea-peaches and other large sea-squirts are familiar to all fishermen on our coasts. They have a sieve inside of them by means of which they strain small organisms from the water after the manner of the salps.

The brachiopods, which look like bivalve molluscs but are really very different, mostly live attached, though a few burrow into mud. Their food collecting mechanism is in general similar to that of the polyzoans and phoronids to which they are supposed to be related. One of them, called the snake's head, is very common in suitable localities on the New England coast below the low tide mark.

Some bivalve molluscs live attached to firm supports, like the oysters of our shores, while many others, like the clams and razors, live buried in the mud. Some, like the mussels, attach themselves with slender silken threads, as all do when very young. The quahogs or hard shelled clams, from which the Indians used to make their wampum, and other forms lie exposed in quiet places on the bottom. A few, like the sea-dates or pholads, bore into rock and sometimes in great numbers into breakwaters, while the ship-worms or teredos, which

are not worms at all but molluscs, tunnel into wood and feed upon it, like the larvae of boring insects in the forest trees. Most of the unattached bivalves can move about, though rather slowly; a few are quite active, like the razor-shells, and the scallops are more active still and can even swim.

Many worms, while not attached themselves, live in tubes of their own construction attached to other objects or partly rooted in the mud.

Of animals which live wholly exposed or hiding away in burrows, holes and crevices and among the roots of plants there are multitudes of conchs, whelks, drills, periwinkles and other snail-like creatures, of crustaceans of very many sorts, and jointed worms of many different types, together with nemerteans, some of which are very large, priapulids, sipunculids and flatworms. Fishes, of course, are everywhere.

Besides the abundance of attached animals, especially of the colonial types, the coastal regions are mainly characterized by the great development of three groups of animals which are almost or quite unrepresented in the open sea. These are the bivalve and gastropod or snail-like molluscs and the echinoderms, including the star-fishes, the brittle-stars, the sea-urchins, the sea-cucumbers or holothurians, and the crinoids. The first two are most abundant along the shore, becoming much less common in deeper water, while the echinoderms rapidly increase in relative abundance with increasing depth. Practically all the members of these three groups are sluggish animals, most of them able only to crawl slowly, though a few bivalves and star-fishes and the comatulids can swim feebly for short distances; some, like oysters and most stalked crinoids, live permanently attached to other objects.

To mention in detail the economic interrelationships of all these creatures would be an overwhelming task; and, indeed, very little is known about them. But let us consider one or two examples.

The common mussel, like oysters and other bivalves, is preyed upon by the common star-fish which is often most

terribly destructive, moving back and forth across the mussel beds in swarms and up and down the piles where mussels grow. We have no figures on the damage done the mussels, but in 1888 on the Connecticut coast alone this star-fish destroyed $631,500 worth of oysters, after not less than 42,000 bushels of them had been taken from the beds. Mussels are preferred to oysters by the star-fish, and some beds have been entirely destroyed by them. Various gastropods, oyster-drills, dog-whelks, winkles, conchs and others eat vast quantities, while killifish, cunners, scup, tautog, squeteague, flounders and cod are very fond of them. In fact, mussels are excellent bait for fish. The walrus in the Greenland seas feeds exclusively on mussels, though the seals, like dolphins, feed on fish and squid. On our coasts mussels are eaten by rats and musk rats, and by such birds as large gulls, ravens, crows and ducks. Within the shells of oysters, pinnas, and the other larger bivalves live flat-worms, known as "wafers," little crabs, small

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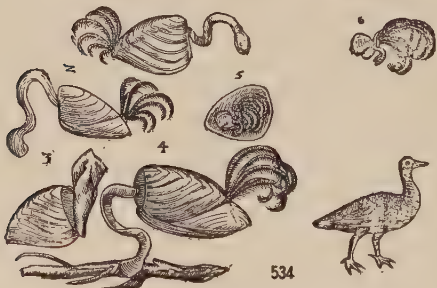

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FIGS. 533–534. The supposed transformation of a Goose-barnacle into a Barnacle Goose.

For explanations of the figures see p. xxviii.

shrimps, and sometimes other things, most of which, except the first, are harmless, or at least do no more than steal the food that they collect.

The very bony crinoids would seem to offer little in the way of food for parasites, yet nearly 150 parasitic or semi-parasitic forms have been described from them. A little groove runs down the middle of the upper side of the pinnules and the arms of crinoids, and the five grooves from the five rays converge to the central mouth. The minute creatures taken from the water are passed down along these grooves in a constant stream which becomes richer and richer as more and more of the victims are delivered to it by the side branches, and at the mouth forms a rich plankton soup. Most of the crinoids' parasites are simply grafters, camping along the sides of this stream and sucking up the soup. About two-thirds of these belong to a curious type of worm, called myzostomes, which, except for two sorts, internal parasites in star-fishes, are entirely confined to them. Crinoids support about two dozen kinds of crustaceans of several different types, a few of which bore into the soft parts but most of which appropriate the food material they collect, either from their ambulacral grooves or from their stomachs. Nearly a dozen kinds of brittle-stars have never been found except upon them, about a dozen kinds of small gastropods bore into them and suck their juices, and they support at least one internal worm and many protozoans. Barnacles, hydroids, sponges, foraminifera, corals, rhabdopleurids, tunicates and bivalves, and curious polyzoans grow upon them, using them as a support to maintain themselves above the mud or sand. But crinoids have one distinct advantage over mussels in that fishes never eat them.

All the sea animals are undoubtedly as complicated in their relationships to others as are the mussels and the crinoids; each feeds upon a more or less extensive list of organisms, and in its turn serves as a source of food for many others.

The enemies of the smaller animals are mostly the larger and predaceous ones. The enemies of the plant-like types are

chiefly the grafters and the food stealers. The enemies of the larger creatures, and the sharks and whales, are the much smaller blood sucking or internal parasites which, though much less conspicuous, are very numerous and just as dangerous.

But the whales and seals have one enemy that makes lions, wolves and tigers look by contrast almost as gentle as pet dogs and pussy cats, and that is the killer whale. This ferocious animal, with an abundance of large teeth, is common in the artic and antarctic seas, and hunts in packs. Its appearance is more sinister than that of any fish, no matter how great the size, except, perhaps, the savage barracuda. I have seen it at close range in Bering Sea and do not care to meet with it again.

The birds of the sea shores call for brief enumeration. The gulls, very numerous in northern regions, are chiefly scavengers, feeding upon whatever is cast up on the beaches or they are able to find upon the flats when the tide is out; ravens and crows compete with them along the shores, but are never very numerous, and are very much less agile on the wing; both these two last prefer to consume their booty in the woods, and often carry shells, star-fish and urchins for some distance inland. Terns and skimmers eat crustaceans and small fish. Fish and sometimes squid form the diet of the cormorants, pelicans, boobies, frigate-birds, tropic-birds and gannets. The reef and night herons catch fish and various of the larger crustaceans, while the very numerous shore birds eat crustaceans, aquatic insects, marine worms, and small molluscs which they mostly catch along the water's edge or on the rocks and beaches, but some, like the phalaropes, also on the surface of the sea. Interesting, but relatively unimportant and not numerous in species, are the fish-consuming hawks, eagles, kites and vultures. The osprey is known to almost every one; so is the bald eagle who often robs him of his prey as the parasitic skuas and jaegers do the gulls and terns. In the Aleutian Islands this eagle is one of the most abundant land birds along the shores, and is much easier to shoot than the

small birds, which here are very shy. In the harbors of the east the kites, soaring over the water on the watch for scraps, look strange to us, accustomed as we are to gulls alone. The condor and the California vulture frequent the beaches more or less, and the nests of the latter often contain mussel shells. Two of the cormorants, one, now extinct, but formerly common in the Commander Islands, the other living in the Galapagos group, one auk, formerly abundant on the north Atlantic coasts but now extinct, and all the penguins, are flightless.

Of other sea-coast creatures there are the seals, which live on fish, the walrus, which lives on mussels, and the sea-otter, now very rare, which eats largely, if not mainly, sea-urchins. The sea-snakes, true snakes and poisonous, yet true sea animals, most of them more helpless on land than eels, the sea-weed-eating iguana of the Galapagos, and the coypu of the inlets of southwestern South America also deserve mention. But the most curious of all the sea-coast creatures is the large fish-eating bat of the Caribbean region which smells strongly of musky fish oil and is abundant at St. Vincent. This bat spends the day in chinks and crevices in the sea cliffs which one would think much too small for it. I once fired both barrels of a 12-bore gun into a narrow crack 15 feet or so above the water and secured no less than 62 of them.

What is the vegetable basis of this abundant coastal life?

On our north Atlantic coasts and on the coasts of Europe this comes from four main sources.

1. Vegetable detritus, or the more or less decayed fragments of the plants growing on the bottom, the sea-weeds and the eel-grass, suspended or dissolved in the water, lying on the bottom, or mixed with the bottom mud.

According to very careful investigations which have been carried on in Denmark all the bivalve molluscs, two snails, all the sea-cucumbers, sipunculids, cumaceans, sea-squirts, ostracods, polyzoans, sponges and foraminifera, and the balanoglossids and cephalochordates, as well as the beach-fly larvae, are purely detritus feeders; the great mass of material in their

FIGS. 535–545. Sea-lilies, Sea-urchins, and Star-fishes.

For explanations of the figures see p. xxviii.

alimentary tracts when analyzed corresponds to the detritus on the ocean floor, and the free-floating plants are only incidentally present. In the deepest water the organic matter is probably chiefly formed by the free swimming organisms dying and raining downward from above.

2. Plants growing on the bottom, chiefly eel-grass, upon which browse certain snails, like the periwinkles, a few echinoderms, and some crustaceans. The Danish naturalists have found that as a basis for the support of the shore living animals these plants are next in importance to detritus.

3. Free swimming microscopic plants, similar to those of the open ocean. The Danes have found that these are of almost no importance on their coasts; their slight value is indirect, through the medium of the free swimming copepods. But probably elsewhere, especially in arctic and antarctic regions where there is no eel-grass and they are enormously abundant, they become of much significance.

4. Drift wood, floating or stranded in the water, and wooden structures, such as piles and wharves. These, essentially vegetable detritus, form the food of curious aberrant bivalves called ship-worms or teredos which bore into them and often cause enormous damage. Other bivalves and various crustaceans, such as the gribble, bore into wood and are often quite destructive, but the teredo is the only creature known actually to live upon it.

THE DEEP SEA ANIMALS

In the open ocean there is abundant plant life at the surface, almost entirely composed of microscopic types upon which feed minute animals endowed with remarkable reproductive powers through which the organic matter is passed on to larger creatures. There are also floating sea-weeds torn from the rocks and drifting with the currents, growing more or less though never fruiting, which serve to some extent to feed the smaller creatures. The gulf-weed or sargassum, so common in the north Atlantic, is the most familiar and important type.

Far below the surface in the twilight zone where the daylight gradually fades to darkness and plant life disappears, in the levels to which most of the surface animals, at least in the clearer and more sunlit portions of the seas, retreat during the day, lurk many predaceous forms which never rise above it. Still further down, in the cold perpetual night where the motion of the waves is never felt, the creatures of the twilight zone pass over into other types, all of medium size or rather small, all good swimmers, and all or nearly all with phosphorescent lights like fire-flies — strange fishes, squids, crustaceans, jelly-fish, etc. — which, becoming fewer and fewer, reach probably to the bottom, those of each level feeding upon the animals from the zone above, and all being supported by the creatures of the twilight zone which at night feed upon the plants. In the north and in the south where the cold water, filled with living particles, is less transparent, and the sun's rays strike it at an angle and do not penetrate so deeply the twilight zone comes almost to the surface and there is little difference between night and day conditions.

Along the shores there is a greater or lesser abundance of

large algae or sea-weeds of many sorts and flowering plants living fastened to the bottom. These are constantly dying and, partially decaying, breaking up into fine particles, this detritus floating about in the water and finally coming to rest in the mud or sand. The microscopic plants of the open ocean of course exist here also, while many kinds of diatoms and similar types live on the bottom and clinging to the weeds. While a few animals here live by browsing on the sea-weeds and the eel-grass, the dominant animal types are sluggish or sessile, or attached and usually arborescent plant-like animals, living on the bottom or traveling over it consuming the detritus, with the more active animals consuming them, especially the shell-fish, crustaceans and echinoderms.

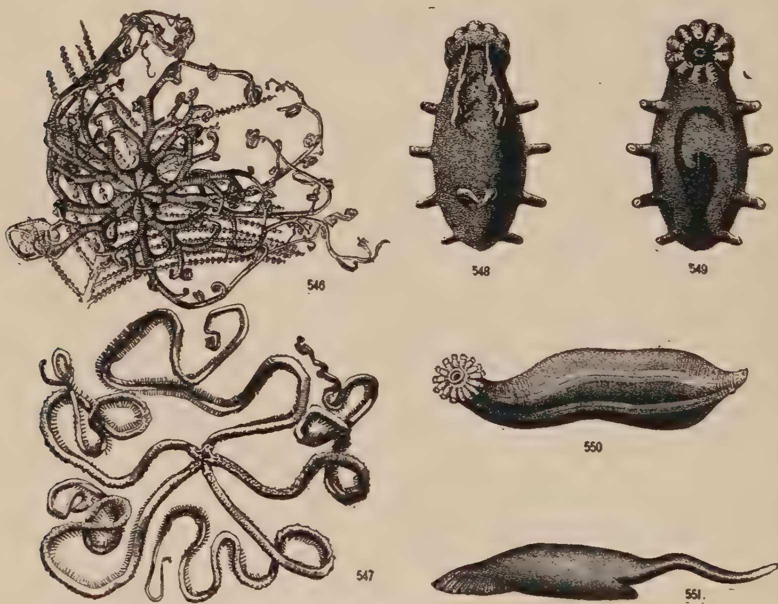
What happens as the sea floor sinks further and further from the surface?

The light gradually diminishes so that in the clearest and most sunlit seas at about 650 feet there is only a pale moonlight at noon on the brightest day, while at greater depths there is no light at all. Wave motion dies away and not far below the surface there is perpetual quiet even in the fiercest hurricane. The temperature declines, rapidly at first and then more slowly; in the abysses it is mostly a few degrees above the freezing point — below it in some places. The pressure increases so that at 15,000 feet it is about two and one-half tons to the square inch.

The number of kinds of animals found between tide marks, in rock pools, on the beaches, or on piling, is relatively small, rapidly increasing from the high to the low water mark. Below the low tide mark the variety of animal life is markedly increased. Beyond a slight depth, 50 feet or so, but varying in different places, within which there are often well marked zones, some of the shore forms disappear, but other creatures take their places and still others constantly appear at greater depths. The maximum variety of marine animal types is found on bottoms between about 600 and 1200 feet where the light is dim to almost absent, the water is cool and very

still, and there is abundant food provided by the shore detritus and the sea above.

Within this zone there are many animals of large size, crabs eleven feet or more from claw to claw, huge urchins and starfish, great plant-like things looking like small apple trees



FIGS. 546–551. Brittle-stars, and Sea-cucumbers.

For explanations of the figures see pp. xxviii, xxix.

(*Primnoa*, etc.), masses of large crinoids, stalked and unstalked, and other creatures, and probably in certain places, swimming about, the giant squids and cuttles.

Below this zone the stillness of the water and the increasing pressure favor the deposit of the finest silt and the bottoms are chiefly of fine mud passing into the so-called oozes made up of the shells of the millions and millions of small creatures constantly dying in the layers above. The greater part of

the sea bottom beyond the coastal muds is formed of globigerina ooze, consisting of the shells of minute shelled animals, the oceanic foraminifera, largely globigerinas, with some bottom living types and a few other things. Less common are the pteropod oozes, made up of the shells of oceanic molluscs, the radiolarian oozes, and the diatom oozes. Toward the middle of the oceans the oozes gradually pass into an excessively fine red mud, which is the typical bottom of all the abysses far from land.

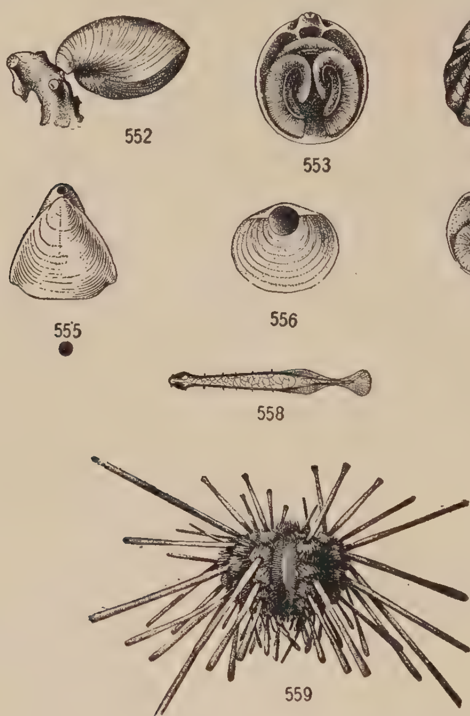
On the red mud everywhere and sometimes on the oozes lie scattered the ear-bones of whales and the teeth of sharks, the only portions of these animals that will persist indefinitely. Some of the sharks' teeth on the red mud are of gigantic size, several inches in length, and came from species long extinct. On the ear-bones and the teeth manganese slowly collects, in time enclosing them in characteristic nodules of various sizes. As over the red mud oceanic life is so scanty as to be practically non-existent, these nodules for the most part probably represent the remains of decrepit sharks and whales which have strayed out here and died.

Below the twilight zone the variety of animal life rapidly lessens, and, on account of the uniformity of conditions in all oceans at these levels, becomes practically the same everywhere.

The basic food here consists of detritus from the plants along the shores, decreasing rapidly in amount with distance from the land, and a correspondingly increasing amount of organic matter derived from the bodies of the creatures in the layers above which, dying, sink gradually to the bottom where further decay is arrested by the perpetual cold and the great pressure which prevent, or at least inhibit, the action of bacteria. The foraminifera, pteropods, diatoms, etc., and the sargassum and other floating sea-weeds dying and going to the bottom carry there at least a portion of their organic substance, which mixes with the mud. This bottom ooze or mud when brought on deck seems absolutely clean, but in the warm air it

soon gives forth a most offensive smell, proclaiming the organic matter it contains.

This mud is swallowed by many of the bottom animals, particularly by all of the numerous echinoderms except the



FIGS. 552–559. Brachiopods, a Chaetognath, and a Sea-urchin.

For explanations of the figures see p. xxix.

crinoids, and by many of the crustaceans, which digest the organic matter out of it, living in the same way that some of their relatives do along the shores. For the other animals, such as the sponges, sea-squirts, stalked crinoids and coelenterates, intermediates are necessary to make this food available, and

these intermediates seem to be the numerous forms of radiolarians and related types which, judging from the long stalks of the attached animals, must in some places form a thin mist for some distance above the sea floor.

Deep sea animals are much more common near land off precipitous coasts than at the same depths further out, in correspondence with the greater density of life in the layers above, and also under cold surface water. They are, after all, only littoral types with sufficiently adaptable natures to enable them to descend to the greatest depths, and fundamentally they differ very much less from the shore types than would be supposed. In the tropics the difference between the littoral and the abyssal animals is great and the change from one sort to the other rather abrupt, but in the cold regions many of the deep sea types come up into shallow water.

The reason why the deep sea animals are most abundant near the land and gradually decrease in abundance and in size with increasing distance from the shores is that nutritive material brought to the sea by rivers and washed from the land by rain upon which the plants subsist is most abundant here. On very precipitous coasts the detritus from the sea-weeds falls into deep water and adds to the supply of food which elsewhere is derived only from the remains of oceanic organisms.

On September 1st, 1924, there was announced from Tokyo in press despatches the discovery of the ocean's deepest spot. This new deep, which like all the other places at which extremes of depth are found, is in the Pacific Ocean and near the land, lies about 145 miles southeast of Tokyo; here the Japanese surveying steamer "Manshu" found 6.18 miles of water — 32,636 feet or 5,439 fathoms.

This depth exceeds the height of Mt. Everest in the Himalayas by 3,634 feet. If we add to this depth the height of Mt. Everest, 29,002 feet, we get the greatest variation in the level of the earth's crust, which is 61,638 feet, or 11.7 miles.

Before the announcement of the discovery by the "Manshu" the ocean's greatest depth was thought to be 40 miles east of

Mindanao in the Philippines where a depth of 6.08 miles — 32,113 feet or 5,352 fathoms — has been determined.

No animal life is known from such depths as these. The animal from the greatest depth so far recorded is a fish (*Grimal-*

FIGS. 560–572. Polyzoans.

For explanations of the figures see p. xxix.

dichthys profondissimus) which was brought up from 19,806 feet, or 3 3/4 miles, beneath the surface in the north Atlantic by the late Prince of Monaco. Many other things, of course, must live at this depth also for this fish to feed upon. It is perhaps worthy of remark that a fish of the same type, a so-called brotulid, lives in fresh water in the caves of Cuba.

It was once thought that the abysses would contain many relics of past ages which had become extinct along the shores. But surprisingly few such relic types have come to light, and

there are not nearly so many of them in the deep seas as are to be found along the shores and in fresh water.

Of all the animals of the ocean floors the mud-swallowing echinoderms are perhaps the most abundant and diversified and the most generally distributed; but all the groups represented also occur in shallow water except for a small number of minor types. The most conspicuous of these echinoderms, because most strange to us, are bizarre sea-cucumbers and starfish, and soft and flexible shelled urchins. Stalked crinoids rooted in the ooze or firmly attached to stones or other objects are characteristic of the deeps, but all the groups represented, like all of those to which the more abundant unstalked forms belong, come up into shallow water, with possibly one exception. The crinoids most important from the standpoint of the life of past ages, the *Pentacrinus* of our text books and the curious *Holopus*, so far from being deep sea animals live, at Barbados, in 30 feet or less so that they can be seen from the surface with a water-glass.

Sponges with silicious skeletons are often very abundant in the deeps, especially near land. One of the chief trials of a deep sea naturalist is sorting over a catch with these things in the mud. Their spicules are sharp as needles, glassy and transparent, and scattered everywhere, so that the sight of sponges always means sore hands. Sailors, no matter how callous they may be toward other forms of life, quickly learn to recognize silicious sponges.

The coelenterates are the only group of animals of which a large proportion of the types are confined to deep water. They are abundant here, and of many different sorts. Especially characteristic are the sea-pens and umbellularians and the curious anemones. There are many corals, largely solitary ones, but no massive types, and numerous alcyonarians and allied creatures.

Various sea-squirts occur, both simple and compound.

Crustaceans are abundant, of all the principal marine groups except the king crabs and the squillas, though barnacles are

poorly represented. They are mostly blind and spiny. There are a few sea-spiders or pycnogonids, some of which are very large; one single kind lives all the way from the shore line down to 13,350 feet below the surface.

Molluscs of all the principal groups except the pelagic occur; one type, called solenogaster, a worm-like thing living on gorgonians and apparently parasitic on them, is most abundant in deep water. The gastropods, or snails, though there are no remarkable forms in the deep sea, are interesting in ranging from at least 16,000 feet below the surface uninterruptedly to above the snow line in the Himalayas.

The fishes are practically all of the bony or teleostean type, and chiefly represent modifications of forms represented at or near the surface in the cold and temperate zones, or which appear as nocturnal oceanic forms. They are small, mostly black or dark sooty brown, sometimes albinistic, blind or with large eyes, and often with long filamentous processes.

Of the remaining animals there may be mentioned the few brachiopods, less interesting geologically than the littoral ones, some sipunculids, the few annelid worms, mostly living in calcareous or quill-like tubes, the numerous radiolarians, and the foraminifera.

From this catalogue one might, perhaps, gather the impression that animal life in the abysses is abundant, which is far from true. A net dragged for two or more hours over the sea floor, an operation consuming almost an entire day, may bring up less than a handful of animals, or even none at all. Rarely, and usually near shore off precipitous coasts, are rich hauls made, such as the one described beyond.

Like their relatives in shallow water, the deep sea animals, especially the echinoderms and sponges and pennatulids, tend to live in colonies, with various crustaceans, worms, etc., associated with them. Sometimes the dredge brings up only the dead remains of such a colony which has died from the exhaustion of the meager food supply or from old age or other cause.

THE OCEAN AND THE LAND

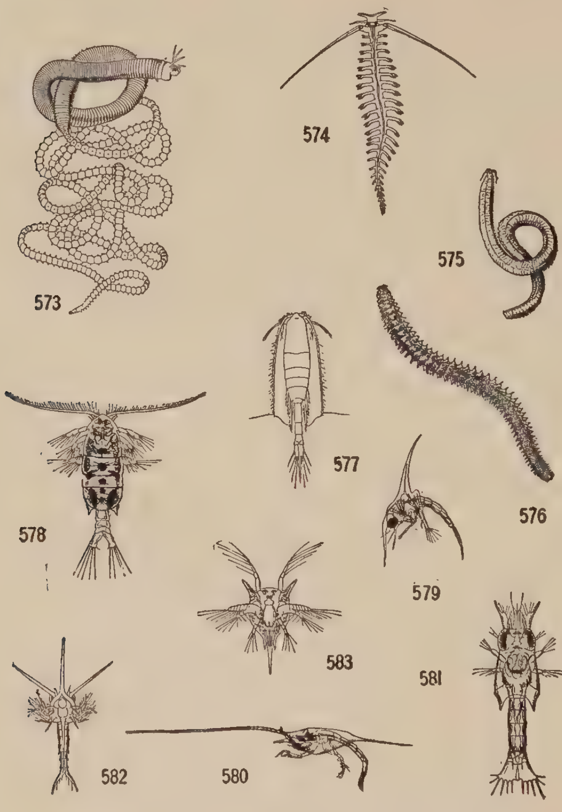
On land there is vegetation everywhere except in the most arid regions, and even there a heavy rain is immediately followed by the appearance of plants of many kinds. The plants are always the most conspicuous living features of every landscape; but they grow only on the surface of the land, rooted in the soil or, more rarely, attached to some support or floating in the water.

In the open sea no plants are ever visible save for an occasional dying rockweed torn from its moorings, though sometimes streaks and clouds indicate masses of diatoms or other minute plants individually invisible to the unaided eye. The visible life of the sea is wholly animal; but the microscopic plants, all of which freely drift about, exist in incredible numbers and occupy a broad stratum reaching a maximum of about 650 feet in thickness in the clearest waters of the tropic seas, but decreasing to a much less thickness north and south where the water is less transparent and where the light is less.

Very few animals feed directly upon the sea plants, and of these only the minute crustaceans are of first importance. These, possessed of only feeble swimming powers, drift aimlessly about and may be said to furnish the chief, though a purely secondary, basis of marine life; though animals, they are to the economics of the ocean what the green plants are to the economics of the land.

In contrast to land animals, most of the smaller and many of the fairly large sea animals, such as the jelly-fishes and the younger stages of such fishes as the ribbon-fishes and the eels, are more or less transparent, some quite so, looking like glass models of themselves.

Never put your fingers into the catch of a tow-net haul without first knowing what is there. Once I was trying to catch a



FIGS. 573–583. The Palolo and other sea worms, and Crustaceans.

For explanations of the figures see pp. xxix, xxx.

paper nautilus without a shell which was swimming about in a bowl of water containing material from a haul off south Japan when a finger was violently seized by something. Exploration with a glass rod and a pair of forceps revealed the presence of

a large and ugly amphipod an inch or so in length, entirely transparent, though quite as tough as any other.

From the surface of the ocean down to great depths animals exist, the number of major groups and of species rapidly decreasing and the size becoming more nearly uniform below the limit of light until in the deeper layers only grotesque fishes, cuttle-fishes, jelly-fishes, crustaceans, nemerteans and echinoderms, are found, all feeding on each other.

A comparison of the animals living in the sea with those inhabiting the land brings out at once a most extraordinary paradox.

About three-fourths of all known kinds of animals live on the land; but this formidable array represents only a few of the major types. The most numerous land creatures are the insects, of about half a million sorts. Equal in importance, much larger, but much fewer both in kinds and numbers, are the vertebrates. Next in significance are the molluscs and the nematodes. Of much less importance are the annelids, including earth-worms, land leeches, and onychophores. The representatives of the other major types found on the land, planarians and nemerteans, are not of much importance in the picture as a whole.

While in the sea there live less than one-fourth of all the animals that so far have been described, these are widely distributed among about three times as many major types as are those inhabiting the land. Certain marine types, like sponges, coelenterates and polyzoans, and some groups of annelids, are sparsely represented in fresh water, which also has some types, like gastrotrichas and the rotifers, quite or almost wholly restricted to it. But of the major types of animals no less than ten (priapulids, sipunculids, phoronids, brachiopods, chaetognaths, echinoderms, enteropneusts, tunicates and cephalochordates), nearly half again as many as all land-living types together, are exclusively marine.

On land different localities and situations are extremely variable as regards the physical conditions. We find hot, tem-

perate and cold, and uniform and changing regions; dry, damp and wet areas, permanent or variable. All these features, together with the chemical variability of the soil, are reflected in the flora of the land, and all these features, plus the superadded features of the flora, affect the animals. In consequence land animals have become subdivided into an indefinite number of different forms or minor types each most efficient within a small range of conditions.

FIGS. 584–585. Discodrilid worms.

For explanations of the figures see p. xxx.

But all land animals have one thing in common; they must seek their food; it will not come to them. Therefore land animals are almost wholly of those types, arthropods and vertebrates, best fitted for locomotion, with representatives of some other types of fair locomotor powers.

In the sea conditions are quite different. The temperature range is small. At no place temperatures of less than 28.4° are to be found, while high temperatures, even in the tropics, are confined to a thin superficial layer. The great bulk of sea water ranges in temperature between 35° and 60°. The chemical conditions are only slightly variable. The salinity varies somewhat, but the different salts are everywhere present in about the same proportion. Motion affects only the surface waters, and is negligible except along the shores.

In the sea food substances float everywhere suspended in the water, drifting back and forth and up and down. While useful, powers of locomotion are not necessary for the creatures in the sea; if they cannot seek their food it will be brought to them.

Thus in the sea the food relations of the animals are of three kinds; some go after it, as do the animals on land; some attach themselves or burrow in the bottom and let the water do the work of bringing food to them; and some float suspended in their food supply.

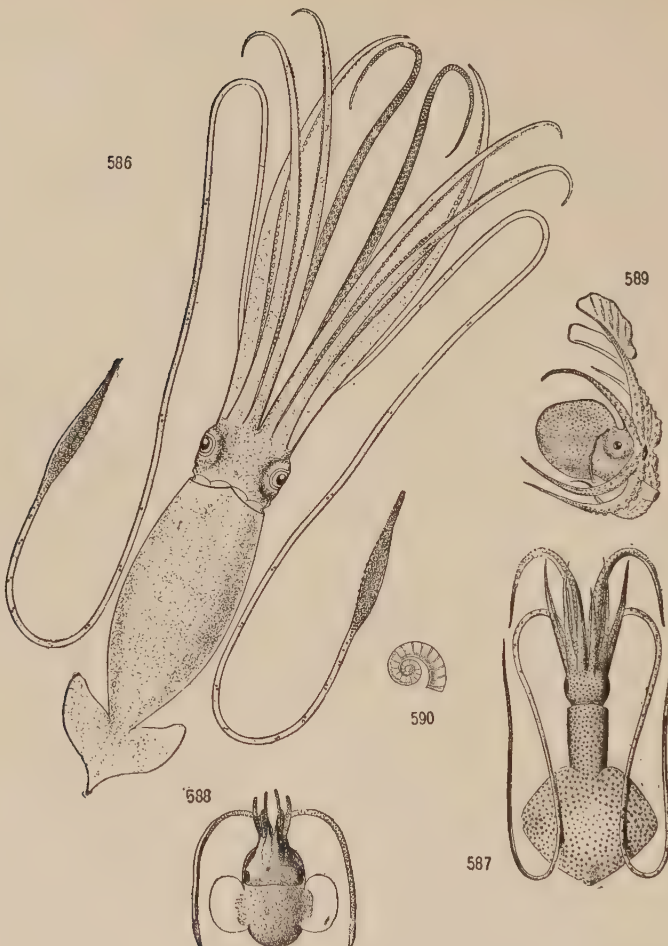
Three possible ways of obtaining food instead of one means a corresponding diversity in the fundamental structure of the animals involved; but the relative uniformity of the physical and chemical conditions in the sea permits the existence of these major types with relatively slight subdivision.

Increase in the height above sea level of the land means not only a gradual decrease in the temperature, but also changes in humidity, in radiation, in air pressure, and in other factors bearing directly on the animal life. The higher the land the more difficult are the conditions which animals must meet, and furthermore the higher the land the greater is the distance to any other similar region and hence the greater the difficulties in the way of the dissemination of the various high land and mountain types.

In the sea the temperatures in any given region and at any given depth are only slightly variable, if at all. With increasing depth the temperatures become gradually lower and more uniform, there is an increase in the gas content of the water, and the distances between similar regions become less and less.

On land the optimum conditions for both plants and animals are in the moister regions of the tropics where the temperatures are high, but not too high, and constant. The tropic lowlands are the paradise of the naturalist, and from this region the variety and bulk of living things decrease north and south, and with increase in elevation. The frost line is an important factor on the land in limiting the ranges both of plants and animals, for by freezing, water is converted to a form in which it cannot be used by plants or animals without a considerable expenditure of energy.

In the sea the colder the water the greater the amount of gases dissolved in it, and consequently the greater the bulk of living things it can support. The optimum conditions for both plants and animals in the sea are found in the Arctic and Antarctic regions in the summer when the sun is at its highest and in the cold currents flowing outward from the polar seas. As the water warms toward the equator life becomes less



FIGS. 586–590. Cephalopods.

For explanations of the figures see p. xxx.

abundant, though more varied, and everywhere it decreases in extent and variability with increasing distance from the shores.

Those curious animals that in our present fauna represent relics persistent from very ancient times are nearly all found in regions where conditions are least variable and approach the optimum, on land in the unchanging tropics, and in the ocean in the colder portions which are free from violent wave action, which means mostly in the deep sea.

FRESH WATER ANIMALS

From our point of view water is water, and to most of us the lakes and ponds seem to differ from the sea only in being fresh while the sea is salt; but the animals are sensible of other and more important differences.

Rivers and streams contain the greater part of the fresh water on the surface of the earth. These are narrow and always comparatively shallow ribbons of more or less rapidly flowing water charged with silt which are ultimately connected with the sea. The water they contain varies in amount with different seasons; in some the shrinkage and expansion is relatively slight, but others in the dry season become reduced to a series of pools, or even completely disappear. The temperature, especially in shallow streams, may be subject to great seasonal variation, and small streams may even be completely frozen in the winter months.

Lakes and ponds and marshes differ from rivers and streams primarily in the absence of a current; they represent surface water from the rains held in a depression, and mostly have an outlet to the sea; if there is no outlet they are usually brackish or saline. They may be permanent, temporary or variable, and may completely freeze in winter. Some large lakes are very deep and were once connected with the ocean, or with ancient seas. A few of these, with no outlet, like the Caspian, are still salt, but in most the water is now fresh. These all have in their fauna typically marine animals, more or less closely related to present oceanic types. In the Caspian and Aral seas live seals related to those in the Mediterranean and Caribbean seas, and to the Laysan seal. But the seals in Lake Baikal are of an arctic type.

In certain plants, especially the bromelias, the bases of the

leaves embrace the stem and serve to hold the water from the rain. So do sagging gutters and discarded pots and pans, while we must keep in mind other receptacles such as vases with cut flowers. In all such situations fresh water animals are always more or less abundant.

In the sea the water is permanent, and remains always, except for tidal action, at the same level; there are currents and counter currents, which decrease in velocity with depth.

Conditions in the sea favor the development of attached and sluggish animals feeding on the creatures passing by and distributed by drifting young, and of more or less inert pelagic drifters.

In fresh water, drifters, unless of very minute size and capable of very rapid reproduction, would soon disappear through being washed ashore or out to sea and lost, and the rich detritus so important in the sea is either smothered in silt or decomposes rapidly, continuously or at certain seasons.

Conditions in fresh water favor the development of amphibious creatures which are capable of living on dry land during some or all of their life stages, or that regularly or on occasion assume a form in which they may be blown or otherwise carried about from place to place.

Occurring in the sea alone, because entirely incapable of meeting the conditions in fresh waters, are the cephalochordates, balanoglossids, rhabdopleurids, cephalodiscids, tunicates, phoronids, chaetognaths, brachiopods, echinoderms, priapulids and sipunculids.

These creatures are either relatively large pelagic drifters (as many tunicates, the chaetognaths, and one echinoderm), mud swallowers requiring a large and constant amount of rich nutritive material in the mud (like the balanoglossids and many of the echinoderms), or they feed on minute drifting organisms of which they must have a constant and a large supply. Of these last those that are not drifters are fixed or very sluggish. They cannot meet the conditions found on the shores of rivers, lakes and ponds, resulting from the fluctuations in the water

level or from the change of seasons, nor can they exist in deeper water because there is not food enough.

The polyzoans, hydroids and sponges are fixed animals having representatives in fresh water; but in all these groups, in contrast to those just named (except for a few mud swallowers), some forms multiply by fragmentation of the young which in the sponges and the polyzoans in fresh water is represented by the formation of statoblasts or gemmules.

FIGS. 591–593. The shell of a Paper Nautilus.

For explanations of the figures see p. xxx.

The most important creatures in fresh waters, aside from some of the larger and deeper lakes, are the amphibious insects, all more or less closely related to others on the land. These mostly live as larvae in the water and fly about as adults in the air; but some are water livers at all stages, though these, too, when adult fly about at night. There are many thousands of such insects, and you find their larvae everywhere, even in bromelia leaves and pitcher-plants, and in tin cans and flower vases. A list of them shows a formidable array.[1]

Of these nearly all the caddis-flies, all the true flies except some mosquitoes, the corethrids, tabanids, leptids, some crane-flies and some stratiomyids, the weevils and the chrysomelids, and the few pyralid moths are vegetarians; a few of the flies

[1] They are the may-flies, the dragon-flies and damsel-flies, the stone-flies, the alder-flies, the dobson-flies, and the caddis-flies, none of which are true flies at all since they have four wings; numerous bugs, such as the giant water-bugs, the water-scorpions, the notonectids, the water boatmen, the veliids, the water-striders, and the hydrometrids; many flies, some tipulids or crane-flies, some moth-flies, the dixid flies, mosquitoes, corethrids, most chironomids, the black-flies, the blepharocerids, many stratiomyids and horse-flies or tabanids, some leptids, a few syrphids, the tetanocerids, most ephydrids, and some others; many beetles, such as the giant water beetles, whirlgigs, haliplids, hydrophilids and parnids, some chrysomelids, and some weevils; and there are even some pyralid moths and hymenopterous egg parasites.

are scavengers. All of the other aquatic insects are predaceous, mostly throughout their lives, feeding on other insects and small crustaceans, sometimes on small vertebrates as well if large enough. Many of these water insects we know as fierce blood suckers in their winged condition.

After the insects the most characteristic animals of fresh water are those amphibious creatures, the frogs and toads and salamanders, none of which live in, and rarely even very near, the sea. The greater part of these when young live in fresh water; most remain near it, and some in it, all their lives. Some toads and salamanders are met with far from water, and some tree frogs spawn in water high above the ground in the axils of bromelias or "wild pineapples" growing as epiphytes or "air-plants" on the forest trees.

Why is it that there are no insects in the sea except for a single type of water strider on the surface and a few on tidal beaches? Why are the toads, frogs and salamanders, and the lung fishes, absent from the ocean?

A great barrier operates to prevent migration to the sea of all fresh water animals, which does not in the least affect an opposite migration from the sea into fresh water — the action of the waves and tides. Any animal type that is in any way adapted to maintain its place against the flowing action of a river current or to travel or be carried overland from pond to pond can pass from the ocean to fresh water. But to pass from fresh water to the ocean an animal must be able to resist the varying pressures of the tidal changes, and especially the action of the coastal and the surface waves at their maximum intensity. A degree of permanent quiet comparable to conditions in fresh water is not found anywhere along the ocean shores or out at sea at a lesser pressure than about two atmospheres.

Insects are all air breathers. The young of water insects, like the adults, have multitudes of little branching tubes within their bodies which reach even to the most minute and distant portions and are always full of air. Some renew the air by

coming to the surface, some by taking it from air in the stems of water plants, while in some the entrances to the tubes are sealed and they are filled by air extracted from the water by gills or other air extracting surfaces. Air being compressible and the insect body being always full of air the insects are incapable of a deep descent in water, for under the added pres-

FIGS. 594–611. Gastropods.
For explanations of the figures see pp. xxx, xxxi.

sure their bodies would collapse. Very few insect larvae could support a pressure of two atmospheres additional. Such insects as can do this counteract the effect of the compressibility of air by carrying part of their supply outside, and usually underneath the body, or between the body and the wings, whereby the added pressure merely decreases the volume of this external surplus and slightly increases the density of the air within the tubes; or they live always at a considerable depth and by gills extract the air at the prevailing pressure at the depth at which

they live. Both systems are practicable in the quiet of fresh water, but neither is adapted for existence in the sea. An insect carrying air outside the body is likely to lose this surplus if subjected to wave action, while the varying pressures on the sea shores, due to waves and tides, prevent the existence there of insects with a closed air reservoir. Free swimming insect larvae, either gill breathing or taking air from the surface, cannot exist at sea for the wave motion, acting as a barrier between the water and the air, prevents their transformation to adults.

Many insect larvae live in tide pools and salt marshes and in the rotting sea-weed on the shores; anywhere, in fact, where they are not subject to wave action or where the wave action is only slight and discontinuous, showing that the saltness of the sea is no deterrent to their existence in it; and I have caught many giant water beetles, water boatmen, and other types of water insects in the tow-net far from land in the summer when the sea was calm.

The air-breathing frogs and toads and salamanders have no ribs, or only very weak ones, and their lungs are therefore subject to the full force of the water pressure. So far as I know none of these are able to support an added pressure of two atmospheres. Neither are any of them large and strong enough to be able to secure a continuous supply of air in stormy weather, and as we know them the gilled larvae are too feeble to withstand the action either of waves or tides.

The sea-cows, seals and whales, crocodiles, water snakes and lizards are large and strong and have their lungs protected by stout ribs and a thick covering of muscles which counteract the water pressure.

Certain gill breathing salamanders live under heavy water pressure, as in artesian wells. But all gill breathing salamanders are feeble creatures, few in numbers, and apparently able to exist only in the absence of wave action and of serious competition. They seem to represent a special type evolved in fresh water, and even in fresh water able to live only in a very circumscribed environment.

In those long past ages which geologists call palaeozoic time wave action on the sea shores was undoubtedly less violent than now. The sea was much less salt, for less mineral matter had been dissolved out of the soil and carried to it by the rivers. Now the less salt there is in water the greater is the vapor pressure and hence the more readily it evaporates, so that in ancient times when the seas were fresher there must have been more water on the surface of the land, in ponds and lakes and in extensive marshes, as well as in the air as clouds.

FIGS. 612–616.
The shells of some bivalve molluscs.

For explanations of the figures see p. xxxi.

Under these conditions, which obtained when the insects were developing as aquatic forms and amphibians were abundant, it would have been less difficult for them to enter the sea than it is at present.

Increasing saltness of the sea rendering more and more difficult evaporation from its surface would gradually increase the amount of water held permanently in the ocean basins, and decrease the amount on the land and in the air. Shrinkage of cloud areas on the land would mean increase of sunlight and hence a marked increase of temperature in the equatorial regions and a decrease toward the poles. With this would come a rise in the strength of winds and the formation of a breaker line along the shores, gradually increasing in extent.

The insects, frogs, toads and salamanders are animals capable of crawling, jumping, running or flying over land when fully grown, but aquatic in the younger stages, truly amphibious, though only found along the shores in very shallow water and absent from the sea.

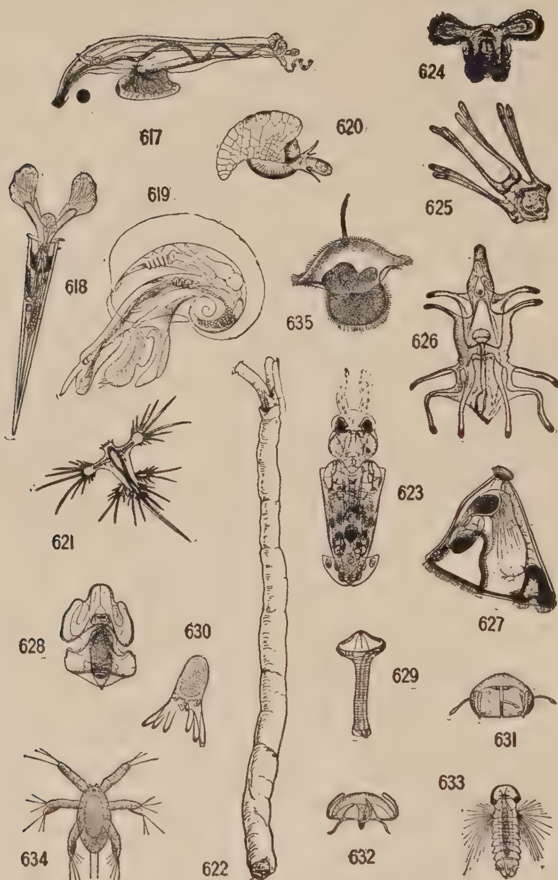
A large and heterogeneous group of animals is very characteristic of fresh water, though all its elements are represented

in the sea. This consists of creatures the reverse of those just mentioned which, wholly aquatic when adult, in their younger stages or as eggs or dormant bits of tissue can be carried overland or through the air.

The gemmules of fresh water sponges and the statoblasts of polyzoans are formed within their bodies; on their death they float away and by their barbed spines become attached to birds and other creatures which carry them from pond to pond. Fresh water clams have curious young like little veil pins which attach themselves to fish or legs of birds. By this means the clams are able to ascend the swiftest streams and to pass overland from one stream to another. Many fish, like perch, have sticky eggs, and these are sometimes carried on the feet of birds.

We have already mentioned fairy-shrimps and how they get about; many other of the small crustaceans and very many of the rotifers resemble these in this respect, while very many of the protozoans are similarly transported in a dormant resting stage.

Thanks to this means of transportation pond life is everywhere about us; our gardens, lawns and trees are dusted with aquatic animals in the egg or resting stages, and they are in our houses almost everywhere. This sounds improbable, I know; but take some withered grass or hay or, better still, bark from the fire-wood in the cellar, and put it in a glass of water. In a week or so the water will be brown and foul with a scum of algae on the surface. Look at a drop under a microscope; it swarms with life, mostly with protozoans and a few kinds of rotifers, but you sometimes find other things. From every different sort of culture you get a different complex of this water life. The richest cultures that I raised last winter were from some leaf-mould from a damp ravine and from the moss used to pack some rose plants sent me. This last yielded gastrotrichas in abundance and copepods and nematodes and other things. Bark dust swept from the cellar floor was very rich, and the finest place I know for vorticellas



FIGS. 617–635. Various marine creatures.

For explanations of the figures see p. xxxi.

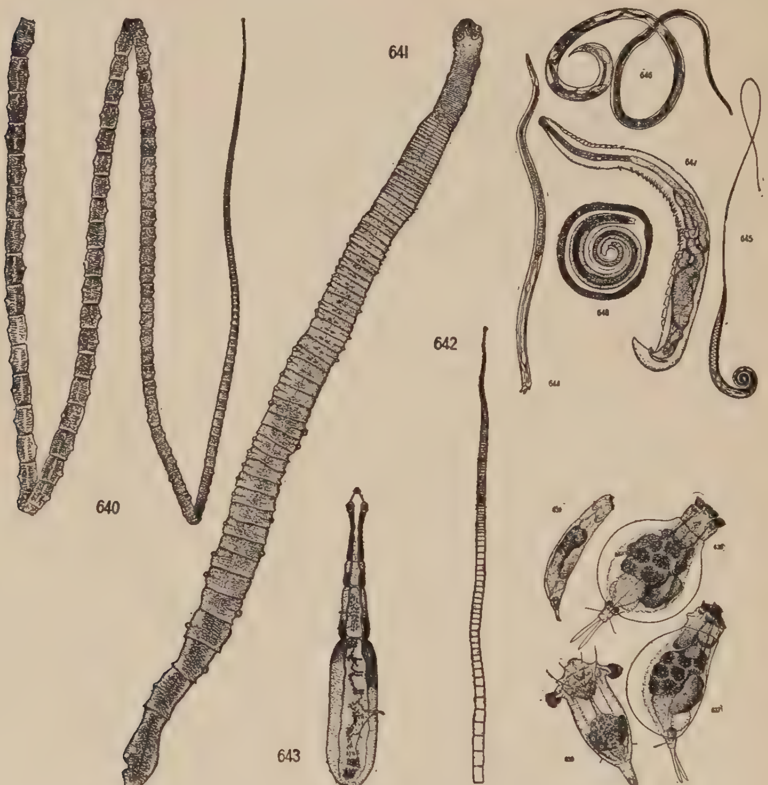
is the bark of a cherry tree in my back yard. The water in the vases holding flowers if it stands long enough will often show peculiar creatures not so common elsewhere. Dead grass or leaves from under snow in winter will surprise you with its productivity. In the summer if you place the cultures out of doors the insects find them, and young mosquitoes very soon appear.

The most impressive lesson that there is in the whole field of nature study is to be learned from hay and water. In such a culture we see on a small scale an epitome of the hideous struggle for existence of each animal type at the expense of all competitors; while at the same time we are forced to an appreciation of the fact that wherever a food reserve is brought together some animal type is ready to consume it. Keep the culture for a few weeks. You will find the balance changes constantly. Some types wane and disappear, others become abundant, different conditions favor different types.

One other group of animals characteristic of fresh waters should be mentioned, consisting of those vertebrates that breed or lay their eggs on land, but feed in water. Chief among these are the crocodiles, caymans, gavials and alligators, such striking features of warm lakes and rivers, which in fresh water largely take the place of sharks. But it should be noticed that one of our crocodiles is marine, or at least chiefly so, as is the largest of the crocodiles, inhabiting the lands about the Indian Ocean and the Malayan and north Australian region. River and pond turtles are common almost everywhere, and some are very large, the alligator turtle of the Mississippi reaching 140 pounds in weight. Another type of turtle is marine. There are numerous more or less aquatic snakes and lizards which eat fish and frogs. One group of snakes and a single lizard are marine; of the former, which are viviparous, all but one or two are helpless out of water. The hippopotamus occurs only in fresh water.

Several animal types chiefly represented in the sea occur also in fresh water. In some of the great rivers of South America,

India and China, live curious dolphins from five to eight feet long, and in South America also sea-cows. Seals occur in



FIGS. 636–648. Rotifers, Nematodes, and Tapeworms.

For explanations of the figures see pp. xxxi, xxxii.

several lakes in Asia. Porpoises are sometimes found far from the sea in rivers.

The fishes, of course, all are related to each other, but in fresh water there are some distinctive types. The strange dipnoi or air breathing fishes all live in rivers, in Australia,

South America and Africa. The ancient ganoids all live in lakes and rivers except for some large sturgeons and garfish which, however, spawn only in fresh water. All trout and salmon spawn exclusively in streams and ponds, though salmon and some trout live mostly in the sea. The brook trout in the north live in the sea in winter, at least along the coast, but in the south stay always in fresh water, as do the land-locked salmon in the lakes of Maine. The Pacific salmon, leaving the river of their birth when very young, do not return until their full maturity, when they spawn and die. The common eel does the reverse and spawns only in the deep sea southwest of the Bermudas, the American and European eels together. Some fresh water fishes in the tropics also spawn only in the sea, though near the land.

Most of the fishes of fresh water are closely related to others in the sea, some very closely, like the sharks and sting-rays found in a few localities about the Caribbean Sea. Some are quite distinctive, but scarcely demand consideration here. Of curious fishes we should note the fresh water flying-fishes of Guiana and west Africa, the electric eels of South America and electric cat-fishes of Africa, corresponding to electric skates and other fish at sea.

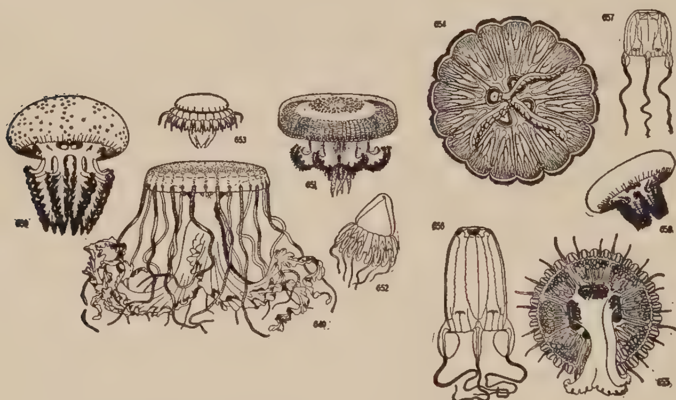
The most ferocious of the fresh water fishes are the cannibal fishes of the South American rivers; others are found in Africa. These are not large, but they hunt in packs and have teeth like razors. They are very good to eat. To catch them you first bait your hook, then heave a large rock in the water; the splash attracts them; they think that it is you. Then you throw your line in and if there are any within hearing distance you are soon rewarded.

Along fresh water shores the conspicuous plants are flowering plants of many types, partially submerged, like pickerel-weed, or floating, like duck-weed, or immersed. There are no "sea-weeds," though there are numerous other sorts of algae, and there are some aquatic ferns and mosses.

Suspended in the water of the larger deeper ponds and lakes

are numerous microscopic plants, the smaller mostly flagellates and algae, corresponding to the microscopic forms in the open ocean. There are many diatoms, as in the sea, and in Lake Mendota in Wisconsin 37,500,000 have been found in a single quart of water. On these, as in the sea, there lives a suspended or pelagic fauna consisting mostly of minute and small crustaceans which is more abundant in the colder than in the warmer regions.

As in the sea, the animals along the shores of ponds and lakes and rivers are the most varied, and with increasing depth



FIGS. 649–658. Jelly-fishes.

For explanations of the figures see p. xxxii.

the number of types rapidly decreases. In the deeper waters more or less characteristic types exist, but there is no such diversified abyssal fauna as there is in the sea.

The pelagic or permanently floating or suspended fauna of the lakes consists almost entirely of small crustaceans. There are none of the pelagic young of larger bottom-living types, and none of the larger drifting forms such as the tunicates, chaetognaths, pteropods, heteropods, ctenophores, siphonophores, etc., so characteristic of the pelagic fauna of the sea. Some fresh

water fishes, perhaps some gastropods, and a few of the medusae might be called pelagic. But poor as it is the composition of this fauna is complex, and like the corresponding fauna in the sea it changes in its aspect with locality and depth and is subject to great seasonal and other variations.

Every body of fresh water has its own peculiar features, yet as a whole the fresh water fauna is singularly constant everywhere.

Let us briefly recapitulate the animals of fresh water. Most characteristic are the insects, the phyllopod crustaceans, the gastrotrichas, the frogs and toads and salamanders, and the air breathing fishes, which are not found in the sea; the rotifers, leeches and aquatic earth-worms, too, are characteristic of fresh water, though there are a few sea types of all. There are very few kinds of jelly-fishes, hydroids, polyzoans, nemerteans or sponges in fresh water, though the few species are usually abundant where they live. Our fresh water jelly-fish is probably much commoner than is supposed; those which I have seen kept wholly to the bottom and only swam when stirred up with a stick. There are no molluscs in fresh water except for snails and river clams and in a few places ship-worms, or teredos, almost no annelids except for those of the earth-worm type, and no barnacles or allied crustaceans. Nematodes are numerous, and there are many flat-worms and very many protozoans. There are very many kinds of fishes, numerous reptiles, and a few seals, sea-cows and cetaceans.

Perhaps it should be pointed out that many nematodes and crustaceans, some frogs, nemerteans, flat-worms, snails, and, rarely, bivalves, live on land or in moist earth, while the cysts or eggs of polyzoans and of rotifers are dusted everywhere.

It is curious that of the two crustacean groups most interesting from the palaeontological point of view one, including the fairy shrimps and their allies, occurs only in fresh, or at least non-marine, waters, while the other, including the king or horse-shoe crabs, is found only in shallow water in the sea; and further that the fishes similarly most interesting, the lung

fishes and the ganoids, live wholly in fresh water, or at least do so when young.

Numerous mammals, like otters, feed wholly in the water, others partly, some occasionally; the sea otter in the ocean represents the otters of fresh water, but most of the water feeding mammals of the land are not represented in the sea, though they may frequent the sea shores on occasion and sometimes fish in quiet backwaters.

Fresh waters have their share of water birds, of all the larger groups except the petrels and their allies, tropic-birds, frigate-birds, and some minor types; and there are other insect-feeding water birds peculiar to streams and lakes, like dippers and jacanas.

There are very many curious features connected with certain creatures in fresh water. A few fish, amphibious, move from pond to pond at night, and in the eastern tropics one sometimes sees them in the roadways. Some sea fish also hop about on mud flats, like ungainly frogs. In the dry season some fish burrow in the mud and hibernate in a large mud cocoon. One arctic fish lives frozen stiff throughout the winter months.

The phenomenon of phosphorescence so striking in the sea and so widely distributed in all the animal types is wholly lacking in fresh water where only the aquatic larvae of some fire-flies give out a light. The curious larval stages which are such an interesting and instructive feature of the life of most sea animals are shortened or entirely omitted in their fresh water representatives.

LIVING LAMPS

From the very earliest times the curiosity of man has been aroused by the power various creatures have of giving out a vivid flash of light or a more or less continuous glow.

When you are camping in the woods at night there is a strange fascination in the fitful greenish "fox-fire" on the surface of rotting logs, now brighter now fainter according to the movements of the air about it; in the shimmering radiance of various fungi, some of which give off light enough to enable you to read a watch face if held close enough; and in the sparkling of the myriads of fire-flies and the glowing of the glow-worms in the damper spots. More uncanny still are those strange lights called "will-o'-the-wisps" seen mostly over swamps and marshes, usually as transient flickers here and there but sometimes as small shining clouds drifting slowly by or rarely as a bright light in rapid motion.

On the sea beaches on dark nights in summer the line of breakers always sparkles with little brilliant points of vivid light, mostly green or bluish, some of which glow for a while when stranded on the mud or sand; and there may be so very many of these little lights that the surf emits a constant steady glow with here and there from time to time some bright and vivid flashes. Higher on the beach beyond the waves you see dead fishes shining with a lovely silver light and as you walk along on the wet sand each footstep is surrounded by a more or less scattered halo of brilliant little sparks.

The dipping of the oars, especially in a muddy harbor in late summer, causes the appearance of multitudes of little lights about the blades; and by watching closely it is easy to perceive that the little lights are of several different kinds vary-

FIGS. 659–664. Jelly-fishes, and a Sea-anemone.

For explanations of the figurės see p. xxxii.

ing in size and color as well as in duration. Sometimes the number of these little sparks may be so very great that the water as it runs off from the lifted oars looks like molten silver and the courses of the fishes swimming down below are plainly evident. The most wonderful exhibition that I ever saw was at Gloucester, Massachusetts, early in September.

On the bottom of the deep sea thousands of feet below the surface where it is always darker than the darkest night almost every kind of creature gives out a brilliant light, and the contents of a dredge haul from these depths presents a truly wonderful appearance. And over the abysses, too, not too far out to sea yet away from the shallow waters of the coasts you find numerous large and brilliant shining things not found near the shore.

Let us begin our consideration of light-producing animals with an account of the so-called luminous birds.

In the oriental countries and in southeastern Europe the phoenix, under various names, has always held an important place in song and story. There are many variations in the accounts of the phoenix. A typical account is that the phoenix, on growing old, built a funeral pyre for itself, kindled it by the fanning of its wings, and was consumed upon it, from the ashes coming forth again in all its youthful glory. But in some places the phoenix was supposed to be a bird which, flashing fire from its plumage, lived wholly in the air; it could not rest upon the ground or in the trees since it had no legs.

From the numerous pictures and descriptions it is clear that the phoenix was usually the Indian peacock more or less altered in appearance by the addition of features taken from various pheasants and the paradise birds, and frequently conventionalized. Sometimes the phoenix as portrayed was almost wholly peacock; again, it was almost wholly pheasant, or a mixture of various pheasants; occasionally it was shown as without legs which indicates an origin in the paradise birds from which in early times the legs were always cut away in skinning. The fire from which the phoenix rose was the

flashing iridescence of the peacock's tail or of certain pheasants' plumes.

The dazzling iridescence of the plumage of many tropical birds such as some of the more brilliant pheasants and the birds of paradise was long thought to indicate that light was given out, and hence that these brilliant creatures were luminous at night.

From the very earliest days in Europe the people have from time to time been frightened by the appearance of night-flying birds which as they passed gave out a steady glowing light. There were very many guesses as to what these luminous birds could be. A common idea was that they were the blue roller, Europe's handsomest bird, which with its glossy plumage looks as if it ought to give forth light at night. But they are really barn-owls with their breast feathers apparently smeared with a luminous fungus rubbed off the decaying wood about the hole which serves as their retreat by day.

In England this phenomenon has been studied very carefully. As a typical example of the appearance of such birds I quote the following from the ornithological report for Norfolk for 1907, by Mr. J. H. Gurney.

"February 3rd.—A luminous Barn-Owl, emitting such brilliancy as to resemble a distant carriage-lamp, was seen at Twyford by Mr. R. J. Purdy and other persons. It was, however, not until December that the existence of a pair of these luminous birds attracted general notice, attention being directed to this phenomenon by Sir T. Digby Pigott in 'The Times.'

"December 1st.—The luminous Barn-Owl which, except for one appearance to Mr. Spencer in October, had not been seen since February, was again observed by Mr. R. J. Purdy, his son, and other persons, shining brightly in the same locality as before.

"December 22nd.—Again the luminous Owl showed itself to Mr. Purdy, and between this date and the 29th it was seen by several people, and by many others subsequently. On the

29th its luminosity appears to have been at its maximum, the branches of trees being even lighted up as it flew amongst them. It was presently joined by a companion, also luminous, but not so bright as its mate, and I am assured by Mr. Purdy that on different occasions one or other of them was seen in six contiguous parishes. The nightly rounds of a Barn-Owl, which are often much the same in line of flight, would not be expected to extend further than that under any circumstances. The light is described by those who saw it best as pale yellow with a reddish tinge; at its brightest it was about as brilliant as the light of a bicycle lamp some three or four hundred yards away, and that was what Mr. Purdy at first mistook it for. Anyhow, the light does not seem to have had the effect of giving warning to Rats and Mice, for Mr. Hamond's bailiff saw it drop on one, and heard the little animal shriek. On one occasion the shining bird was quietly seated on a gate, and another time on the ground, having probably just dropped in pursuit of a mouse. Those who saw it best agree that it was much brighter when coming towards the observer, and especially when rising in the air, but so much did the light pale as it flew away in the contrary direction that it is certain that little, if any, of the glow proceeded from the back of the bird . . ."

In 1908 Mr. Gurney remarked that sufficient evidence had been brought forward to prove that luminosity in nocturnal birds is after all not so very rare a phenomenon, though seldom approaching the exceptional brilliancy of these (and other) Norfolk owls, but often enough to be the origin of a good many will-o'-the-wisp stories.

The one and only bird actually known to shine at night is the barn-owl of western Europe, which does not shine by its own light, but through the intermediary of a fungus sticking to its feathers. The barn-owl in this country. almost identical with the European one, apparently is never luminous.

Among the tree frogs there is one kind found in Europe which exudes from the surface of its body a shining substance having luminous properties.

One of the smaller earth-worms, nearly world-wide in its occurrence near the coasts and found with us as far north as Washington, secretes a luminous mucus when disturbed which gives off a greenish yellow light.

Under logs and stones you sometimes find very slender centi-

FIGS. 665–668. Hydroids.

For explanations of the figures see p. xxxii.

pedes, quite different from the common stouter ones. At certain times these slender centipedes are brightly luminous, the light spreading out over the whole under surface of the animal. If one is taken up the luminous secretion comes off upon the hand as in the case of the luminous earth-worms.

In some of these the upper side is also luminous, the head lighting up with a bright greenish light which spreads back-

ward toward the tail until the whole body glows; then the light slowly fades away, beginning at the head.

These luminous centipedes live everywhere in the warmer regions. In Europe luminous individuals are only found between the end of September and the beginning of November, never singly, but always in pairs or companies of three or more. In tropical countries they have been found shining at various seasons.

A small collembolan, found under stones and logs, gives out a little spark of light of extremely short duration.

Certain of the gnats or chironomids are sometimes afflicted with a luminous disease, and when this happens the little clouds of dancing insects appear as a thin phosphorescent haze drifting slowly with the wind. Such infected gnats are not rare in Europe, but in this country are very seldom seen. They constitute one of the three forms of will-o'-the-wisps, another being the luminous barn-owls, as explained above, and the third and commonest the giving off of gas by decaying organic matter in the swamps which bubbles up and becomes ignited at the surface of the water, resulting in a brief and feeble flicker.

Foremost among all the luminous creatures on the land are the fire-flies and glow-worms.

There are two entirely different types of fire-flies. The first of these belongs to the family of click-beetles or Elateridae and includes about one hundred kinds which are found from the southern United States southward to Chile and Argentina, and also in the New Herbrides, New Caledonia, and Fiji. These fire-flies have a luminous oval patch on either side of the thorax, or the section between the head and wings to which the latter are attached, and a much larger more or less triangular patch on the under side where the thorax and abdomen join. In flight they tilt the abdomen upward so that this last is expanded to the full extent. They are extremely brilliant, both sexes about equally. They fly in more direct lines and give out their light more continuously than our common fire-flies.

Beneath them you sometimes see a bright spot following them along caused by the beams of light from the luminous patch on their under side. Not only are the adults luminous, but also the grubs or larvae, the pupae, and the eggs.

In parts of the West Indies and in Mexico they are kept in little cages of wicker work or wire netting or used by women for personal adornment, entangled in their hair or fastened to their clothing. They are captured by waving a burning coal toward which they fly. When kept as pets great care is taken of them. They are fed each evening on pieces of crushed sugar cane, and bathed twice every day in tepid water.

The common fire-flies are found in almost every country, but the greater part are from America, especially the warmer portions. They belong to a very different group of beetles called the Lampyridae. Their luminous organs are on the under side of the abdomen, more or less differently distributed in the different kinds, but usually near the tail. Most of them give out their light in flashes, which are different for each kind. In some the females have no wings and look like larvae; these wingless females are called in England glow-worms. With us glow-worms are the wingless females of some kinds, and the larvae of others. The grubs or larvae of these fire-flies are also luminous; they are predaceous, feeding on snails, earth-worms, and other creatures. The embryos within the eggs are also more or less luminous. A few of our fire-flies have the light organs very much reduced so that they give out only a little spark, and some, which fly by day, produce no light at all. The young of some of the oriental sorts live under water feeding on aquatic snails, and are the only phosphorescent creatures in fresh water.

The so-called glow-worms in New Zealand are found in colonies in caves, mines, and other damp and shaded situations where they spin a mass of sticky threads upon which their prey becomes entangled somewhat after the manner of the spiders. These are not real glow-worms, but the young or larvae of a sort of fungus gnat. The hinder end of the body is

brightly luminous, giving off a light bluish green radiance. In the pupae the tip of the body is also luminous, and the same region in the adults emits a steady light about half as bright as that of the young.

The larvae of another fungus gnat which live gregariously beneath a sticky web on the under side of certain toad-stools are also luminous, their whole body shining. The pupae are also luminous, but the adults are not.

Some years ago the larva or grub of one of our click-beetles (*Melanactes piceus*) was described as luminous and so figured; but the figure represents a female fire-fly of the sort called *Phengodes*, a grub-like creature an inch and a half or so in length with a series of bright lights on either side. This mistake has been several times repeated. The same insect was at about the same time recorded as a luminous milleped.

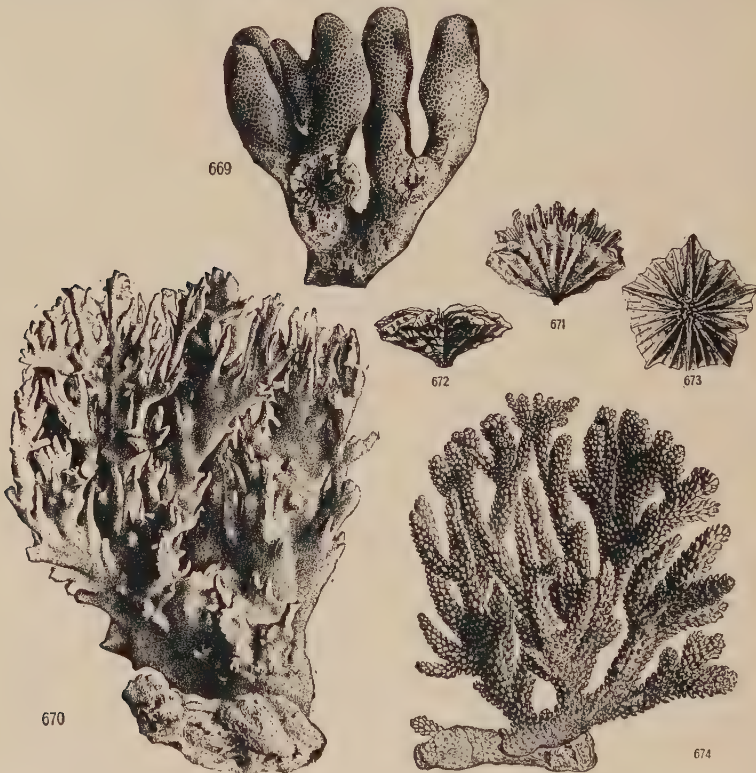
Once in Trinidad a friend of mine, enjoying the refreshing evening coolness in the Botanic Garden, saw some fiery teeth suddenly appear before his face. Startled he jumped back, and the teeth moved rapidly away. They were the teeth of a large bat which had been eating fire-flies. Sometimes night birds also render their mouths and beaks luminous by eating fire-flies.

Before leaving the subject of luminous insects it is perhaps worthy of remark in this connection that an Indian bird has the curious habit of catching fire-flies and sticking them in the mud about its nest as if to serve as lamps.

Among the creatures on the land the ability to give out light is rather rare, perhaps because of the brilliant illumination by the sun for twelve hours, more or less, each day. But in the sea where animal life is most abundant, at some depth beneath the sun-lit surface and in the less illuminated regions north and south, very many, if not most, sorts of animals give out a light.

An unusual exhibition of phosphorescence at the surface was thus described by Lord George Campbell, one of the watch officers on the "Challenger."

"We left St. Iago (Cape Verde Islands) on August the 9th, steering to the southeast, and taking the usual soundings, etc.,



FIGS. 669–674. Corals.

For explanations of the figures see pp. xxxii, xxxiii.

till the third degree of north latitude, when we steered westward to our destination — St. Paul's Rocks.

"On the night of the 14th the sea was most gloriously phosphorescent, to a degree unequalled in our experience. A fresh wind was blowing, and every wave and wavelet as far as one could see from the ship on all sides to the distant horizon

flashed brightly as they broke, while above the horizon hung a faint but visible white light. Astern of the ship, deep down where the keel cut the water, glowed a broad band of blue, emerald-green light, from which came streaming up, or floated to the surface, myriads of yellow sparks, which glittered and sparkled against the brilliant cloud-light below, until both mingled and died out astern far away in our wake. Ahead of the ship, where the old bluff bows of the "Challenger" went ploughing and churning through the sea, there was light enough to read the smallest print with ease. It was as if the 'Milky Way,' as seen through a telescope, 'scattered in millions like glittering dust,' had dropped down on the ocean, and we were sailing through it."

Of this same night Professor Moseley wrote that the ocean as far as the eye could see was lighted up with sheets of a curious weird-looking light, and whenever the water broke a little on the surface before the breeze the white foam was brilliantly illuminated. So bright was the light, indeed, that the lower sails of the ship were seen to be distinctly lighted up by the radiance given off from the broken water thrown up by the hull of the vessel.

Such a wonderful scene as this is very rare. In this case it was caused by millions upon millions of a minute organism called *Pyrocystis*, then for the first time discovered.

After a calm day at sea there rise up to the surface with the gathering darkness all sorts of living things which sink down again at dawn. If the sea is rough they do not rise. But on this occasion after a calm day the breeze rose with the coming darkness surprising all these creatures at the surface, and hence the magnificent display.

Most commonly the ocean when the water is disturbed is seen to be full of scintillating specks with now and then a brighter flash and occasionally a bright and slowly fading glow.

Mr. Alexander Agassiz remarked that the greater number of the pelagic animals are phosphorescent; and when the sea is calm and the other circumstances favorable these animals are

individualized by the greenish, golden, or silvery light which betrays their presence and defines their outlines, while it illuminates the sea itself. Sometimes, but not often, on tempestuous nights the phosphorescence, intensified by the motion of the water, adds singularly to the wildness of the scene. Each wave rises like a mass of molten iron and seems to threaten the vessel with destruction; it breaks, then passes off in her trail, and adds new beauty to her brilliant wake. In this general illumination Mr. Agassiz observed that it is easy to distinguish the different forms of life. The huge ctenophores float by like luminous balls among the myriad lesser lights caused by the smaller jelly-fish, while the Portuguese men-of-war resemble fire-balloons on the surface and spread the phosphorescence in all directions.

As described by Moseley, when a large fish or a porpoise or a penguin dashes through water full of little luminous creatures their bodies are brilliantly lit up, and their tracks are marked by a trail of light.

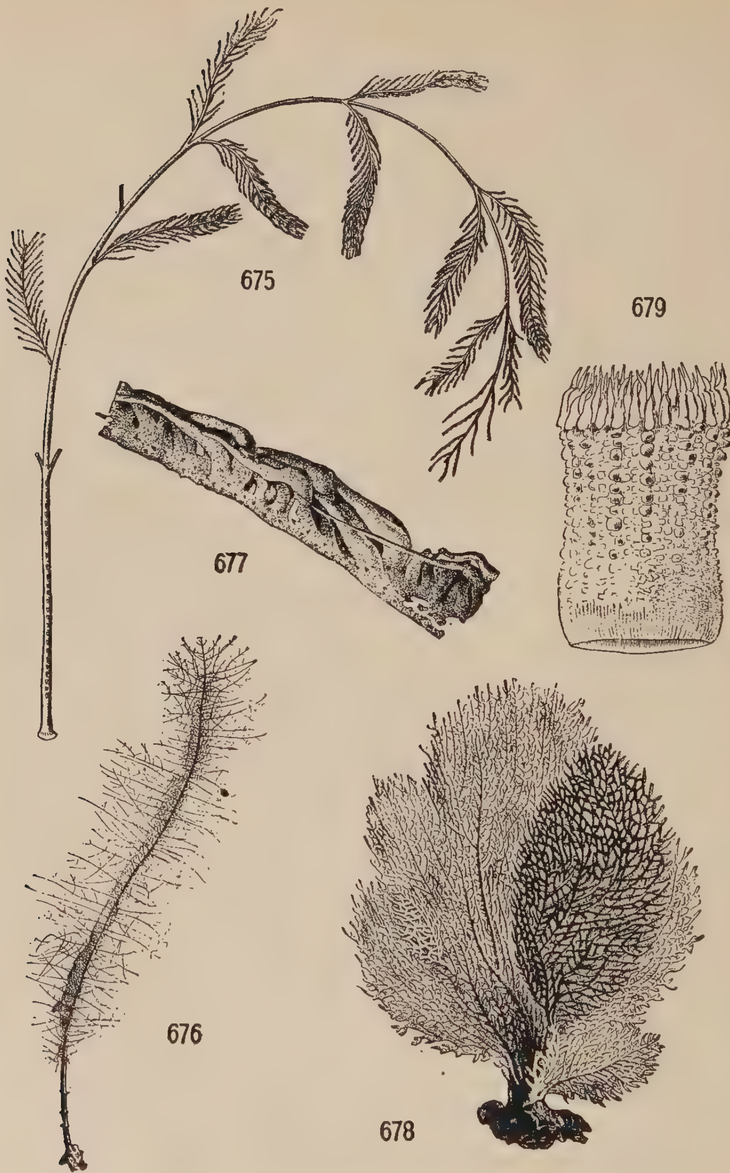
An excellent sketch of the conditions on the bottom in the depths of the Norwegian Sea has been published by Professor G. O. Sars. As he describes it, forests of those peculiar sponges known as *Cladorhiza*, with tree-like branches, here deck the bottom for long stretches. Among the branches of these *Cladorhizas* are beautiful sea-scorpions or basket-stars, variegated "fire-stars," and various crustaceans, while slow moving sea-spiders or pycnogonids creep about these branches and with their long proboscis suck out their organic juices. And among the dead sponges a whole world of more delicate plant-like animals flourish. In the open spaces between the sponge forests beautiful purple star-fish creep about, and long armed brittle-stars, together with numberless jointed worms of various kinds, and round about different sorts of crustaceans swarm. Above all else project, like high mast timber in a coppice, the umbellularians, some eight feet high, with their delicate straight stems and elegantly curved crowns formed of a group of polyps. The light of day does not penetrate to these great depths, but

as a compensation there is produced by the animals themselves a splendid illumination of the whole, inasmuch as almost all are strongly phosphorescent, with the power of producing from their bodies an intense light, bluish, greenish or reddish.

Of the animals living on the bottom of the deep sea very many, if not most, are brilliantly phosphorescent, and the mud that comes up with them is full of luminous specks. Most striking are the alcyonarians and sea-pens and their allies all, or nearly all, of which are brightly luminous, white, lilac, or greenish blue, the light fading and increasing in different parts with a wave-like action. Several of the brittle-stars shine a lovely brilliant green all over, the light fading and reappearing; others shine brightly at the joints. Some of the star-fishes are almost or quite as bright, and many of the jointed worms or annelids are very brilliant.

Speaking of a dredge haul in 3600 feet of water off Cape St. Vincent Sir Wyville Thomson said that the trawl seemed to have gone over a regular field of a delicate simple gorgonian with a thin wire-like axis slightly twisted spirally, a small tuft of irregular rootlets at the base, and long projecting polyps. The stems, which were from 18 inches to two feet in length, were coiled in great hanks around the trawl beam and entangled in masses in the net; and as they showed a most vivid phosphorescence of a pale lilac color, their immense numbers suggested a wonderful state of things beneath — animated corn fields waving gently in the slow tidal currents and glowing with a soft diffused light, scintillating and sparkling at the slightest touch, and now and again breaking into long avenues of vivid light indicating the paths of fishes or other wandering denizens of their enchanted region.

Speaking of some dredge hauls made northwest of Scotland Sir Wyville said that in some places nearly everything brought up seemed to emit light, and the mud itself was perfectly full of luminous specks. The alcyonarians, the brittle-stars, and some of the jointed worms were the most brilliant. The pennatulids, the virgularians and the gorgonians shone with a lambent



FIGS. 675–679. Various Coelenterates.
For explanations of the figures see p. xxxiii.

white light so bright that it showed quite distinctly the hour on a watch; while the light from one of the brittle-stars was of a brilliant green, coruscating from the center of the disk, now along one arm, now along another, and sometimes vividly illuminating the whole outline of the star-fish. Of this same brittle-star, as brought up between the Shetlands and Stornoway from 2064 and 3360 feet of water where it lived in a temperature considerably lower than the freezing point of fresh water, he says that he was greatly struck with the brilliancy of its phosphorescence. Some of the hauls were taken late in the evening, and the tangles were sprinkled over with stars of the most brilliant uranium green; little stars, for the phosphorescent light was much more vivid in the younger and smaller individuals. The light was not constant, nor continuous all over the star, but sometimes it struck out a line of fire all round the disk, flashing, or one might rather say glowing, up to the center; then that would fade, and a defined patch, a centimeter or so long, break out in the middle of an arm and travel slowly out to the point, or the whole five rays would light up at the ends and spread the fire inwards. Very young ones just transformed from the larval stage shone very brightly.

Coming down the Sound of Skye from Loch Torridon the "Porcupine" dredged in about 600 feet, and the dredge came up tangled with the long pink stems of the singular sea-pen *Pavonaria quadrangularis*. Every one of these was embraced and strangled by the twining arms of a long-armed brittle-star. The *Pavonarias* were resplendent with a pale lilac phosphorescence like the flame of cyanogen gas; not scintillating like the green light of the brittle-star, but almost constant, sometimes flashing out at one point more brightly and then dying gradually into comparative dimness, but always sufficiently bright to make every portion of a stem caught in the tangles or sticking to the ropes distinctly visible.

Let us review briefly the types of animals that are responsible for this remarkable display of luminescence.

No creatures anywhere are more remarkable than the various

phosphorescent fishes, of which there are very many different kinds. Nearly all of these are of small size. Most of them live in the open ocean below the sunlit upper layer of water, some coming to the surface after dark; but a number are bottom livers, and a few live in shallow water on the shores.

In the Caribbean Sea and Gulf of Mexico and on the west coast from California to Chile there is a curious type of toad-fish (*Porichthys*) provided with numerous little luminous spots arranged in several lines.

The so-called "Bombay duck" is a strange fish occurring on the coasts of India and in the East Indies, normally inhabiting deep water, but at certain seasons coming to the surface. It is caught in large quantities on the western coast of India, salted and dried, and exported from the Malabar and from Bombay. When freshly caught this fish is brightly phosphorescent, though it has no special light organs.

There are two fishes living in shallow water in parts of the East Indies which have special highly luminous spots combined with an arrangement for covering up the light. These fishes are peculiar in that it appears their light is not of their own creation, but arises from luminous bacteria which live upon them in special regions formed for their reception.

Some of the fishes living at the surface, especially the flying-fishes, if you cut them open in the dark emit a brilliant light which comes from the many luminous creatures they have eaten.

A little fish common in the Caribbean called the ballyhoo or half-beak has the point of the lower jaw greatly produced with a light organ on the tip.

A number of phosphorescent fishes are like the "Bombay duck" in being luminous all over, shining with a greenish glow. Some of the macrourids are of this nature. Lieut.-Col. Alcock says of the fish called *Leptoderma* that the whole skin seems to be transformed into a phosphorescent overcoat.

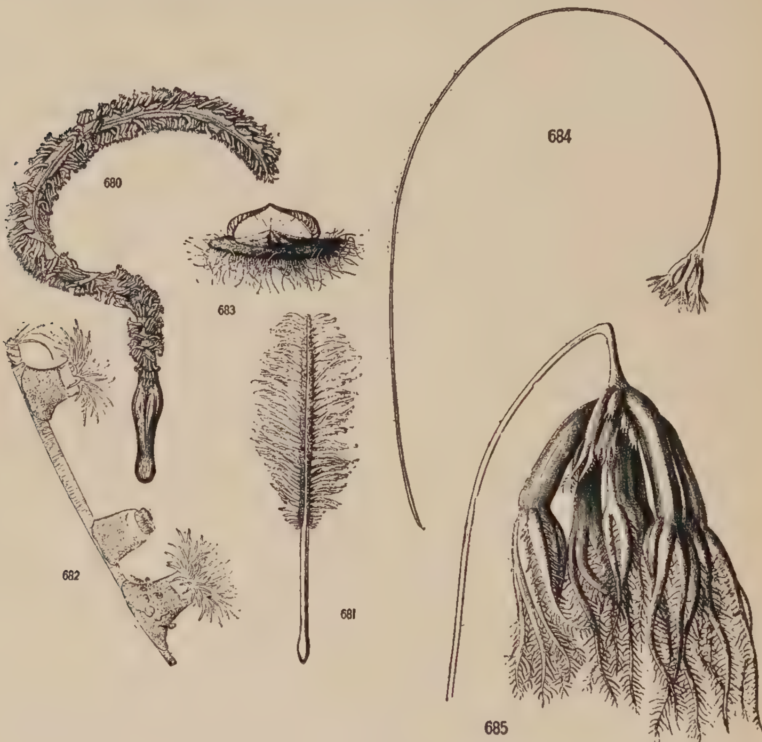
About a dozen kinds of little sharks are luminous. In one caught by the "Challenger" the entire lower surface of the

body and the head emitted a vivid greenish phosphorescent gleam, imparting to the creature a truly ghastly and terrific appearance. In all these little sharks the light is given off from large areas of the skin, especially on the lower side and head.

More than two dozen different types of light emitting organs are found among the fishes, some very simple, others exceedingly complex with a structure more or less like that of eyes, but fitted to send out light rays instead of to receive them. Indeed, the eyes themselves may be transformed into phosphorescent organs. Luminous organs in the fishes are situated mostly on the head, or on the head, sides, and lower surface. Many fishes have rows of little lights along their sides so that they look like little steamers with all the port holes lighted. It is a very curious fact that many of the luminous fishes are wholly blind.

If you stand at a steamer's stern at night and watch the myriads of sparks and flashes in its wake you will see from time to time large and brilliant glowing objects usually a foot or so in length. These are the *Pyrosomas* or "fire-bodies," each a hollow cylinder made up of very many little tunicates all growing close together. You find these in all seas over deep water, though they are scarce and rather small in the Caribbean and in the Gulf of Mexico, and they disappear completely in the mid-Pacific. Of the *Pyrosomas* not all kinds are luminous, though most of them seem to be, and when they are they are extremely brilliant, appearing as cylinders of fire, reddish, yellowish, blue or greenish, sometimes appearing as of mixed colors. Professor Huxley found that a *Pyrosoma* he examined was at its brightest red, fading through shades of orange, green and blue. When suddenly shaken by the passage of a steamer a *Pyrosoma* lights up all at once and glows for a considerable time. If one be taken in the hand the portions touched immediately light up and the illumination spreads, increasing in intensity, in all directions until the whole mass is aglow, then slowly fades away, with occasional local waves of brightness.

Professor Moseley wrote that on the "Challenger" a giant *Pyrosoma* was caught in the deep-sea trawl. It was like a great sack with its walls of jelly about an inch in thickness,



FIGS. 680–685. Various Coelenterates.

For explanations of the figures see p. xxxiii.

four feet in length and ten inches in diameter. With his fingers he wrote his name on the surface of this giant *Pyrosoma* as it lay on deck in a tub at night, and in a few seconds his name came out in letters of fire.

Among the other tunicates some of the salps are often very bright, the chains glowing with a white and more or less

steady and continuous light. Mr. Alexander Agassiz wrote that in the Gulf of Mexico he found a salp chain far exceeding in size any of those known before — a huge band several yards in length and a foot in breadth, which at night, when seen from the deck, seemed like a huge veil of bright greenish phosphorescence. He noted that one of the smaller kinds of salps gives out generally a bluish light.

The tunicate called *Doliolum* gives off a greenish light, and some of those curious things called appendicularians shine very brightly, reddish, white or green.

Very many of the small crustaceans give out a brilliant flash, from almost white to greenish or bright blue in color, and some are luminous even in the earliest stages. Many of the little copepods are very bright, but the most surprising things of all are the little ostracods abundant in some places in the east, an example of which is the Japanese "sea fire-fly." It is almost unbelievable these little things can produce the amount of light they actually do. Some of the schizopods have long been famous for their brilliancy, and there are other luminous oceanic types with various sorts of light organs differently distributed, sometimes in their eyes.

Many of the larger bottom living deep sea crustaceans give off copious clouds of a ghostly blue light from near the bases of the antennae or the eyes, sometimes from other places.

Most of the luminous crustaceans live in the open ocean or on the bottom at great depths; there are very few along the shores.

Luminous sand-hoppers or beach-fleas are sometimes seen. These animals are not really luminous, but they are affected with a luminous disease caused by bacteria which gives off a steady greenish light.

Occasionally the dredge brings up non-luminous crabs or hermit crabs with dense tufts of luminous plant-like animals growing upon them.

Some of the pycnogonids are brightly phosphorescent. Lieut.-Col. Alcock mentions one dredged off the east coast of

the Andamans in 5532 feet of water the span of whose lanky legs was nearly 20 inches. The creature as it lay on its back shone like a star, all its legs being lit along their under surface with a strong greenish blue radiance.

Among the molluscs some squid and octopus found along the coasts gleam all over with a whitish light, and some shallow water squid have special light organs. None of the octopus from the deeper water are known to shine; but many of the deeper water squid have most elaborate light emitting organs rivaling those of fishes. In one of these there are 24 such organs; each of the elongate arms bears two; there are five around the lower border of each eye; and the remainder are on the lower surface of the body. Professor Chun describes this creature as set with a diadem of variegated jewels, some brilliant blue, some mother-of-pearl, and some of ruby red.

Of the other molluscs a number of the bivalves are quite brilliant, such as the rock boring pholads. A number of the univalves or snail-like types are also luminous, as are several of the pteropods and heteropods. The light emitted by these molluscs is mostly greenish or a vivid blue, but in some reddish. The luminous molluscs live mostly in the open sea.

A number of the jointed worms or annelids living on the surface of the sea or in deep water are very brilliant, as are also not a few of those that live along the shores concealed in holes or under stones. Some of the latter swarm at the surface at certain seasons and produce a wonderful display, a few leaving trails of light behind them a foot or two in length.

As an example, Mr. Agassiz wrote that a most surprising phosphorescense was produced by a small annelid allied to *Syllis* which he found in Petite Baie d'Arlet. Just after dark this bay was covered for a time with hundreds of phosphorescent spots gliding slowly about, when suddenly a number of these began to move actively, performing the most remarkable gyrations. Soon the whole bay was traversed by brilliant phosphorescent trains made up of small particles of light, which remained refulgent for a while, so that the track, winding

swiftly in and out, backwards and forwards, could be distinctly made out till the light became exhausted. After a period of rest the process was repeated.

Of the curious arrow-worms or chaetognaths a few are phosphorescent, as are some of the sea planarians and rotifers.

Of the echinoderms very few are phosphorescent, only a few brittle-stars and those strange star-fishes called *Brisingas*. But these are often very bright. On the coast of Europe the common brittle-star (*Ophiothrix*) as it occurs between the tide-marks, is never luminous, at least when large. But the same sort from deeper water glows with a pale greenish light.

On our coasts and elsewhere there live buried in the mud curious brittle-stars remarkable for the great length of their arms. These are luminous on the under side, showing a double row of lights on each of the long rays. Some of the other kinds that live along the shores hidden under stones or buried in the mud are also luminous. One dredged by Mr. Agassiz in the Caribbean, like one of the Mediterranean kinds, was exceedingly phosphorescent, emitting at the joints along the whole length of its arms a bright bluish green light.

Our two most conspicuous jelly-fishes on the New England coast, the translucent whitish *Aurellia* so common in late summer and the red *Cyanea*, are never luminous. But many other jelly-fishes, large and small, are remarkable for their bright and usually whitish flashes. Looking over a steamer's stern watching for *Pyrosomas* you often see bright flashes quickly fading. These come from jelly-fishes, usually from one known as *Pelagia*.

Most of the ctenophores give out a brilliant flash, greenish to almost white. In some even the very youngest and the eggs are luminous. Exposure to sunlight or to any other light if sufficiently prolonged diminishes or completely destroys the power of emitting light among the ctenophores, just as in the case of the West Indian fire-flies.

Siphonophores are often luminous, like most of the other jelly-fishes usually only in special regions.

The brilliant phosphorescence given out by sea-pens and related forms living on the bottom in deep water has already been described. Mr. Agassiz has noted that in the Caribbean

FIGS. 686–695. Hydroids, a Siphonophore, and Sponges.

For explanations of the figures see p. xxxiii.

several sorts of gorgonians and of antipatharians showed a bright bluish light as they came up in the trawl. These plant-like things growing on the bottom are among the most brilliant and most beautiful of all the phosphorescent animals. A few

that live in shallow water, including certain corals, are also luminous, giving off a greenish light.

Some polyzoans have been described as luminous; but this needs confirmation, at any rate regarding those that live along the shores. Luminous sponges have also been recorded, but there is doubt whether the light came from the sponge itself or from the creatures on and in it.

Occasionally in the East Indies near the shore the water glows with a continuous uniform somewhat milky light which is not affected by the movement of a ship. This is caused by luminous bacteria in countless millions.

The black and white water of the Arctic, the so-called feeding ground of whales, is mainly made up of diatoms with which are also found various pelagic animals.

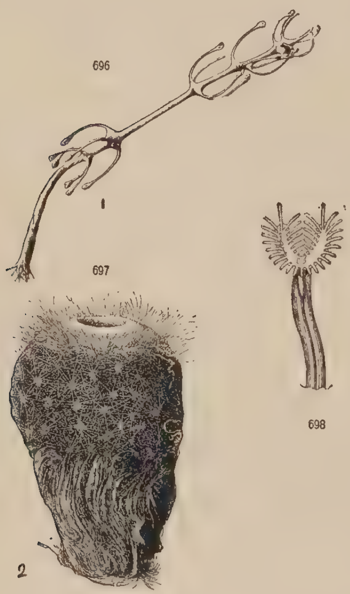
While it has no connection with phosphorescence, it may be here remarked that the color of the Red Sea is due to a minute alga or sea plant which forms huge patches of a blood red tint. A similar phenomenon was described by Darwin on the coast of Chile and Peru, where Mr. Agassiz also saw it. It occurs also in the Gulf of Mexico, though here the long trains or patches are of a dirty yellow color instead of brilliant red. On one occasion Mr. Agassiz found this same plant coloring the surface of the sea a dirty yellow for an area of about a quarter of a mile in length by a hundred yards in width north of Cape Hatteras.

An illumination, uniform in color, somewhat similar to the bacterial, but on examination seen to arise from myriads of minute sparklets, generally observed in a somewhat ruffled sea and best seen along the sides of a moving ship, originates according to Steuer usually from flagellate infusorians.

Vanhöffen has remarked that the small sparks of the infusorians and the minute crustaceans and medusae are to the flashes of the large medusae and the *Pyrosomas* as the small stars in the sky are to the full moon passing through light clouds.

On our New England coast in the late summer and in early

autumn the peridinians become excessively abundant, and the magnificent displays of phosphorescence sometimes seen are due to them. Elsewhere, too, in the Mediterranean and on the coast of western Europe and at various places in the tropics the peridinians are abundant and important as light producing organisms. At Nassau, in the Bahamas, in Waterloo or Fire Lake the wonderful exhibition is due to a local peridinian.



FIGS. 696–698. Two Sponges and a Phoronid.

For explanations of the figures see p. xxxiii.

In the North Sea, in the Yellow Sea, and elsewhere, the *Noctilucas*, looking like minute spheres of transparent jelly, take the place of peridinians. Their light is bluish or greenish, like that of peridinians, and they are sometimes present in enormous numbers, 30,000 or more to each cubic foot of water.

Pyrocystis, which caused the display recorded by the people on the "Challenger," gives a steadier light than the peridinians or *Noctilucas*.

Some, at least, of the radiolarians are phosphorescent, but observations on these are very few.

The luminosity arising from dead fishes on the beach is caused by the bacteria growing on them, and the light generally appears about a day after they have died.

The light given off by living animals and plants is usually bluish green to green or blue, sometimes lilac, purple, or even pink or red. It sometimes varies in color with intensity. Its spectrum is very short, falling mostly in the green and blue,

rarely ranging from the red to violet, and shows no lines. As light it is very nearly perfect, with practically no non-visible emanations.

Before we leave the subject of animal light we must notice briefly the glowing of the eyes of cats and similar phenomena. This is not due to any light originating in the eyes themselves, but to reflected light from a source behind or in front of the observer and near his line of vision, and it varies in intensity with the light reflected. Thus in the bright light from automobile headlights the eyes of dogs and cats, rabbits and deer, often shine like electric lights themselves.

Generally speaking mammals' eyes shine brightly blue or green, more rarely white. Perhaps the brightest are those of wolves, coyotes and some dogs, which shine a dazzling white, and of hyaenas, which show a tinge of red. An automobile headlight will sometimes pick them up a quarter of a mile or more away, gleaming like little electric lights. With a dimmer light, as of an oil lamp, most dogs' eyes shine greenish.

Everyone has seen cats' eyes shine green. Wild cats' eyes shine the same but are much brighter, like the large eyes of the lemurs. Lions' and tigers' eyes shine also green, but are not so bright as wild cats'.

Opossums' eyes are very bright, white, almost like little electric lights. The eyes of rabbits and of deer shine blue or bluish white; horses' and cattle's eyes are similar, but duller.

In contrast to the eyes of other mammals our eyes shine a dull red, like the eyes of crocodiles and birds. Small children's eyes are usually quite bright, and the red reflection is easily observed if you place them in the dark with a light coming from behind you. Boys' eyes soon cease to shine. The eyes of girls usually shine longer, and sometimes women's eyes shine almost all their lives.

Very few birds' eyes will shine at all. But the goatsuckers, including our whip-poor-will and chuck-will's-widow, have eyes that gleam a vivid ruby red and are conspicuous for a long distance. Mr. H. S. Barber and Dr. Alexander Wetmore have

tried to shine the eyes of owls, but all they could get was a faint dull red or orange glow.

Dr. E. R. Dunn and I last summer shined the eyes of a little salamander; they showed light greenish blue.

The eyes of certain spiders are extremely bright, shining a piercing green and visible for a hundred yards or more. So vivid are they that at first it seems impossible that they can really be the eyes of spiders.

If you examine the ordinary moths that gather round a light in summer you will see their eyes give out a reddish glow which sometimes is quite bright.

Let me repeat that the shining of these eyes has nothing at all to do with luminescence. The glow is merely the reflection of a light originating from outside the animal, even though it usually seems to be given off by the eyes themselves.

LIFE'S BORDERLANDS

No picture is complete without its frame. Let us therefore frame our presentation of the animal life upon the earth with a consideration of life's borderlands, an outline of the extreme limits within which animal life exists.

Suppose someone should say that there were millions of animals now living which had never experienced a temperature as high as that of the cakes of ice in the ordinary refrigerator. Such a statement at first sight appears incredible, and yet it is perfectly true.

In the winter when the ground and ponds are frozen the plants cease to grow and become dormant. The turtles, snakes, lizards and frogs, the butterflies, bees, ants and other insects, the snails and the earth-worms, all pass into the long sleep known as hibernation, and the only active living things about us are the winter birds and mammals. All birds are perpetually active, and all of them that cannot find sufficient food or stand the cold go south; but some mammals, like the bears, hide away and sleep throughout the winter, while many others, like the squirrels and the field mice, sleep most of the time, appearing at intervals on warm and sunny days.

It is evident, then, that on land the activity of most living things comes to rest at a temperature of about 40°, or at the lowest at the freezing point of water, a substance essential for the support of life but one which few creatures can use in the form of ice because of the great expenditure of energy necessary to reduce it to its liquid condition, in which condition alone can it be utilized.

In certain portions of the sea, deep down where the heat from the sun never penetrates and where it is darker than the darkest night, there is perpetual winter with an absolutely

unchanging temperature of below 30°, well below the freezing point of fresh water. At the temperature found here our lakes and ponds would be solid blocks of ice; but salt water freezes at considerably lower temperatures than fresh so that in these frigid depths no ice is formed. On land animal activity almost entirely ceases when the water freezes; in the sea the water is still water and available for use by animals when it is colder than we ever see it.

Along the western shores of the Okhotsk and Japanese Seas there is a broad band of this very cold water, and here animal life is so exceedingly abundant as to challenge comparison with any other region in the world. It was on September 26th, in 1906, on the coast of Sakhalin that we found the coldest bottom, with temperatures ranging from 29.8° to 30.4°. But my most vivid recollections are of our first experience with such conditions. This occurred in the Sea of Japan on July 19th, a warm and sunny day with the air from 80° to 82° and the surface water of the sea 76°. The temperature on the sea bottom below was 32.4°, not quite ice cold but very near it, cold enough to make it pleasant for the same animals that are found in the coldest places.

The dredge went down and was hauled up while we, dressed in white, kept so far as possible in the shade. The haul was successful, and a wealth of animal life fell into the sieves when the net was opened. With enthusiasm we commenced sorting the many and varied creatures before us; but our enthusiasm slowly waned as with perspiring bodies and almost frozen hands we more and more carefully picked out the treasures, now a fish, like an animated piece of ice, now a crab or starfish, or a sea-urchin, or a plant-like creature, or a wretched flabby thing into which our fingers sunk most painfully. And none of these animals had ever in their lives experienced a temperature more than four-tenths of a degree higher than that of the ordinary cake of ice.

There are various other regions where the sea bottom is just as cold as here or even colder, in the Arctic and Antarctic, and

in the deep waters of the Norwegian Sea, and in all these places with temperatures between 28.4° and 32° animals are especially abundant.

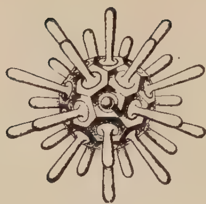
Almost everywhere on land for at least part of the year the temperature rises above the freezing point. Even if the ground be perpetually covered with snow or ice there will be little warm islands consisting of the dark patches of dirt lying on the snow which will support a number of different plants and various insects. Such isolated verdant spots are often an interesting and conspicuous feature of glaciers.

A few warm days in winter incite to activity numerous kinds of flies, moths, wasps and other insects which fly or crawl about and then, when the sun gets low or when the cold returns, become again inactive, falling apparently lifeless on the snow. One of the commonest, most conspicuous and most active of these types is the little snow flea.

In the colder parts of the northern hemisphere there is a strange insect, a wingless tipulid — crane-fly or daddy-longlegs — which reverses the usual habit of insects in living in summer as a grub or larva under decaying leaves and becoming an active adult in the coldest months of the year. These insects are most active in cold snowy weather from January to April, even when the temperature is below zero, walking rapidly across the surface of the snow in perfectly straight lines. It has been noticed in April that if in the morning the sun shone brightly causing a slight thaw a few would be visible; but if the weather changed in the afternoon and became colder with a flurry of snow large numbers would come hurrying from all directions. They are very sensitive to warmth and will die in a few minutes if carried in a warm hand.

There is another insect belonging to an entirely different group, a wingless panorpid or scorpion-fly, looking somewhat like a young grasshopper, which has similar habits.

If animals thrive in very cold water, do they thrive equally well in high temperature? They do not, for a number of different reasons. On visiting a museum or reading a book on zo-



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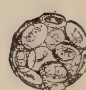

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FIGS. 699–708. Minute sea organisms.

For explanations of the figures see p. xxxiv.

ölogy you are astonished at the contrast between the few sea animals from the Arctic regions and the bewildering array of types from the tropical seas. Corals of many sorts, some of them of huge size; enormous shells, both conchs and clams, the latter sometimes weighing thousands of pounds; immense sea-urchins and equally large star-fishes; crabs and shrimps of scores of different kinds; and a vast assortment of other things. You naturally conclude that life is much more abundant in the tropics than it is in the north. I have examined many coral reefs in different parts of the world, but compared with the incredible abundance of animals on very cold bottoms or on the northern coasts where the bottom is suitable, tropical reefs appear singularly barren. True, the number of different kinds of animals on the reefs, corals, shells, star-fishes, anemones, sea-urchins, sponges, crabs, worms, etc., is enormous, vastly greater than the small number of kinds in the cold sea; but the actual bulk of all the animals taken together is very much less, and there are no such living animal carpets such as we often find in the north.

Yet there are a number of animals that enjoy remarkably high temperatures. The larva of a stratiomyid fly is reported to have been found in a hot spring in Gunnison county, Colorado, in water with a temperature of 157° F. In a hot spring in Uinta county, Wyoming, the larvae of a stratiomyid fly were found in water so hot that the hand could not be held in it, the estimated temperature being not more than 20° or 30° below the boiling point. In hot springs in Owen's Valley, California, a spider-like animal and small red worms were found in water having a temperature of 124°. The little crustacean known as *Cypris* has been reported from hot springs with a temperature of 122° F., while microscopic ciliated animals and rotifers have been found in water of which the temperture is given as 149° F. In the Yellowstone Park a little insect known as *Salda* was seen running about the edges of springs which were actually boiling, and two species of an insect called *Nebria* were found living under pieces of geyserite even on the

sides of the cones of the largest spouting geysers where they were liable to be washed away in a flood of boiling water.

The maximum temperatures at which plants can exist have been carefully determined, and it has been found that certain of the so-called blue-green algae may occur in some abundance in water with a temperature of over 154°, and they will even live in springs with a temperature of from 167° to 170°, only 42° below the boiling point. Indeed they have been reported from higher temperatures, up to 199°, though these records need confirmation. Thread algae have been found in water with a temperature of 176°.

Animal life in such situations as these is, however, infrequent. In fact most animals, even in the tropics, are rather sensitive to excessive heat, especially dry heat. In a very hot and arid part of Venezuela I noticed that certain beetles when disturbed would drop at once to the ground, a common habit among weevils and some other types, where, exposed to the terrific heat of the sand, they soon died, victims of the only means of escape from an enemy they knew.

On the surface of the earth all living things exist under a pressure of one atmosphere, becoming slowly less with increasing altitude, which means that every square inch of our bodies is continually under an air pressure of 14 3/4 pounds, and our whole body under a pressure of about 14 tons. Water is about 814 times as heavy as air, so that in the sea the pressures under which animals live are much greater than on land, and they increase rapidly with depth — about one atmosphere for every 32.8 feet. What effect does this have upon the animal life in the sea? Strange to say, practically none at all; at least the effect is so much less than that of the changed conditions of light and temperature and altered food conditions at great depths that it is not evident. The bodies of sea animals being composed mostly of water they may be said to be transparent so far as that liquid is concerned.

In the Pacific on the run between Yokohama and the Hawaiian Islands the "Challenger" made a successful dredge haul

in very deep water, bringing up the bottom animals living on the sea floor 17,400 feet, or three and a third miles, below the surface in a perpetual winter night where the unchanging temperature was 35.3° F. At this depth the pressure is about 535 atmospheres, or roughly four tons to the square inch; which means that if you could put your hand into this water it would be instantly crushed by a pressure of over 100 tons, the weight of a good sized locomotive; or that if you fell overboard here and sank to the bottom, escaping the attentions of the sharks on the way, you would finally come to rest under a pressure of 7,490 tons.

Exclusive of the minute animals called protozoans there were found in the net over 70 specimens of fishes and invertebrates, representing 32 different kinds, including 5 kinds of bivalve molluscs, 4 of sea-anemones, 3 of star-fishes, 3 of worms, 3 of sea-cucumbers, a shrimp-like animal, a sea-urchin, a sea-lily, a coral, a brachiopod, an antipatharian, and a hydroid, all of which there is not the slightest doubt were living on the bottom.

Rivers and most lakes are fresh and the sea is salt, and we all know that in both salt and fresh water fishes and numerous other living things abound. There are, however, certain lakes, like the Dead Sea, the Great Salt Lake, and Mono and Owen's Lakes in California in which the water contains much more solid matter in solution than does the water in the sea. In the shallow artificial ponds called brine pans where salt is extracted from sea water by natural evaporation the density of the brine of course is very high.

Can anything live in water so saturated with salt that the salt is crystallizing out? The brine-shrimps are happy nowhere else. These dainty and delicate little creatures are exceedingly abundant in Mono and Owen's Lakes, in the Great Salt Lake, in the Dead Sea, and in many brine pans all over the world. They will thrive in water with a salt content of 271 grammes per liter and with the color and consistency of beer. They will also live at rather high temperatures, and are found abundantly in water of 80° and over. In the Great Salt Lake their food

FIGS. 709–740. Protozoans, marine and parasitic.

For explanations of the figures see p. xxxiv.

consists of the smaller fragments of brownish simple plants called algae which are very common in this salt-laden water.

In our western saline lakes, at least in Mono and Owen's Lakes, the only other visible inhabitants are the young of the *Ephydra* flies which, as already described, are so greatly esteemed by Indians as food. It is these brine-shrimps and the *Ephydras* that attract the myriads of gulls and other water birds so often seen about these salt lakes and ponds.

In the spring time in our woods and on our plains we often see more or less extensive pools and ponds which disappear later in the season. In such ponds the fairy shrimps, close relatives of the brine-shrimps, are often abundant, swimming slowly about back downward. Here in these isolated temporary ponds they are quite safe from fish or other water creatures, though not from birds. Their life is short and they soon disappear, but not before sowing the bottom with great numbers of their eggs. When the pools dry up these eggs mingle with the dust and by the summer winds are blown about. In winter they are frozen in the snow and ice. But in spite of the drying and the freezing and the rough treatment by the summer winds when spring comes once more they hatch and for a few weeks we see again the fairy shrimps.

Other kinds of fairy shrimps are abundant in the Arctic regions everywhere in the ponds and tundra pools, swimming about for a few weeks in the short Arctic summer, but spending most of the year as eggs in the frozen ground.

Caves, far underground, often contain pools and ponds and sometimes streams of considerable size. In such waters, always beautifully clear and quiet, there live many strange creatures as uncanny as their surroundings. The most conspicuous of these are ghastly white or slightly pinkish fishes without eyes, of several kinds, and similarly ghostly salamanders. In our American caves there are found half a dozen or more crayfish or crayfish-like things, all without eyes but with the eye stalks remaining. About half of our fresh water amphipods or sand fleas live in caves or wells or springs, and many of them are

completely blind. Some of the fresh water isopods, too, a group represented by the little sow-bugs or pill-bugs of our woods, are eyeless and live in caves, while the only known representative of one type was, together with other equally strange crustaceans, brought up from an artesian well in Texas. All of our fresh water types of larger crustaceans, in fact, except the mysids of the Great Lakes, have developed forms adapted to life in subterranean waters; and in Europe there is a cave fairy shrimp which is curious in sometimes having normal eyes, sometimes being completely blind, and sometimes being blind in one eye only. Many insects, especially certain crickets, and some spiders, abound in caves. For the most part these are types which are found elsewhere in deep holes and crevices protected from the light; but a few seem to be special cave-living types.

The catalogue of unusual situations inhabited by animals might be extended almost indefinitely, but the preceding examples will suffice to indicate broadly the limits between which animal life exists.

Active animal life is found at a constant temperature of 28.4° F. (at which sea water freezes at the surface, though not when under pressure), at a constant temperature of about 157° F., and at all intermediate temperatures, constant or more or less widely varying, ranging, therefore, through about 128.6° F. In a dormant or inactive condition animal life can withstand the coldest temperatures on the earth's surface, becoming active again when the temperature rises above the freezing point. Birds and mammals are independent of the temperature about them; they maintain continually a high temperature within their bodies which are insulated from the air by fur or feathers, and they can spare sufficient energy to transform snow to water, if they do not get the latter from their prey. A few insects, as adults, remain active below the freezing point, but these neither eat nor drink.

Animal life can exist permanently in complete darkness, in caves, underground, and in the abysses of the sea.

Animals can live on high mountain tops where the air pressure is only about 13 inches or even less, about 6 1/2 pounds to the square inch, and in the ocean deeps under a water pressure of about 600 atmospheres, or about 9,000 pounds or 4 1/2 tons to the square inch.

It is interesting to note that of all animals the gastropods or snails have the greatest range, living from above the snow line in the Himalayas to at least 16,000 feet below the surface of the sea. Of the vertebrates the fishes live from high mountain streams down to a depth of feet 19,806 below sea level, though always in water. Of the birds the condor soaring about the Andean peaks in an air pressure of 13 inches or 6 1/2 pounds to a square inch, can without injury to himself drop down to the sea shore where the air pressure is 30 inches or 15 pounds to a square inch.

THE IMPORTANCE OF BIOLOGICAL RESEARCH

MAN lives in a world replete with other forms of life competing with him for his food supply and even striving to consume the very substance of his body. Human existence is a constant struggle with the insects and the other things that consume the grains and other crops, the cattle and the poultry, and with the diseases that consume the flesh.

Most of us live far within this battle front and are unappreciative of the constant warfare carried on in our behalf by the farmers and the doctors. But when this battle front is pierced and swarms of army-worms or locusts devastate our crops, or brown-tails or gypsy-moths destroy our trees, or influenza kills us by the thousands, we are for the moment cognizant of our constant peril.

Our army and our navy are our protection from outside aggression, while our police protect us from the internal enemies of our social order.

Our farmers grow the crops and stock by which we live. In doing this they spend their lives in constant costly warfare with the insects. The number of people who could be fed by the wheat or corn or other grain destroyed by insects or clothed by the cotton or wool lost every year represent the casualties on this battle line. We discount these casualties as "losses to the farmer." But take these numbers and read them as "losses to our army" and see what that would mean. The two are really alike in being both losses to our man power and all that that implies.

The weapons of the fighting armies always represent the highest attainable perfection of the moment. We know that this is necessary; we also know our fellow men. The farmer does the best he can, but his weapons seldom represent per-

fection, while the hordes which he is called upon to meet are merely "bugs" to him.

Each "bug," however, is as distinctive in its way as is the human race itself and must be thoroughly understood in order to be vanquished. And hordes of alien "bugs" exist in other countries of which the brown-tailed moths, the gypsy-moths, the cabbage butterflies and boll-worms are but samples waiting to cross the sea to us.

Our farmers have no time to spend on the details of entomology, or in the study of the parasites that infest their animals and fowl, any more than our soldiers have time to perfect themselves in the mathematics of range-finding, or in the details of the chemistry of the explosives used in war. The soldier knows that if he sets his sights for 600 yards, takes aim and pulls the trigger, the ball will carry true and he will get his man. His confidence in the mathematicians who designed his sights and in the chemists who prepared his powder is so implicit that he never gives a thought to them, but takes their work for granted and is quite justified in doing so.

How about the farmers and their war against the "bugs?" Most farmers stand where armies stood three hundred years ago, when powder was a treacherous thing, too unreliable for mathematics, and armies had to face largely with swords and pikes wild and savage tribes with unknown implements of warfare.

Chemistry and mathematics and that form of social understanding called diplomacy have made the modern armies what they are. Chemistry and mathematics and a similar understanding of the life history, habits and proclivities of his enemies, insects and parasites, will do the same for farmers. Just as the modern army owes its effectiveness to the labors in the past of a relatively small minority of men, largely unconnected with a military life, so the farmers in the future more and more will be dependent on the labors of the research students who, by concentrating on some special line in entomology, parasitology, chemistry or other science and spending all their lives

investigating special problems, will form their diplomatic, ordnance and small arms departments.

In their knowledge of their foes and how to meet them our farmers are three hundred years behind our soldiers; and if we compare the potential casualties represented by insect depredations, by loss through parasites, or by imperfections in our knowledge of plant and animal breeding and in similar ways with the casualties in the armies of the world the differential is still greater. We have only just begun the task of giving to our farmers that organized assistance to which they are entitled.

How about our fishermen and those who live along the coasts? In the not distant future when the cultivation of the land has reached its limit and no further increase in our crops is possible we shall have to cultivate the sea as well and from it take the food to feed our surplus population.

In the field of oceanography we have an enviable record, equalled by no other nation; yet all that we have done is so far in the nature of preliminary work; no detailed survey of the economics of the ocean as a whole as yet has been attempted anywhere. The study of the ocean is still far behind the study of the land, and our sea resources are all but unappreciated. It is in this field that research on a broad and generous scale is most urgently required in order to insure our future.

Just as the police serve to maintain order within our social units, both by preventive and by coercive measures, so do the doctors serve to keep our bodies healthy both through the prevention of infection and by direct attack on all forms of disease. When we fall ill we think at once of doctors. We know that medicine has conquered scurvy, typhus, malaria and yellow fever, and made possible the Panama canal. But do we realize that we are dealing here with applied biology and that most of the knowledge embodied in modern medicine has resulted from the work of relatively few research men who were more biologists than doctors, of whom the public rarely hears, yet whose work is fundamental?

Each new discovery in any line of scientific work complicates the subject by increasing the multiplicity of detail; the growing mass of facts necessitates restriction of the individual's activities to a narrower line of work if he is to know his subject as he should. The narrower the field of labor, the more detached the worker from the general public whom he serves. But let not this blind us to the value of his work and the necessity, greater every day, of according him adequate support.

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